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Worldwide Report

NUCLEAR DEVELOPMENT AND PROLIFERATION

No. 41

Indian Department of Atomic Energy

Annual Report 1978-79

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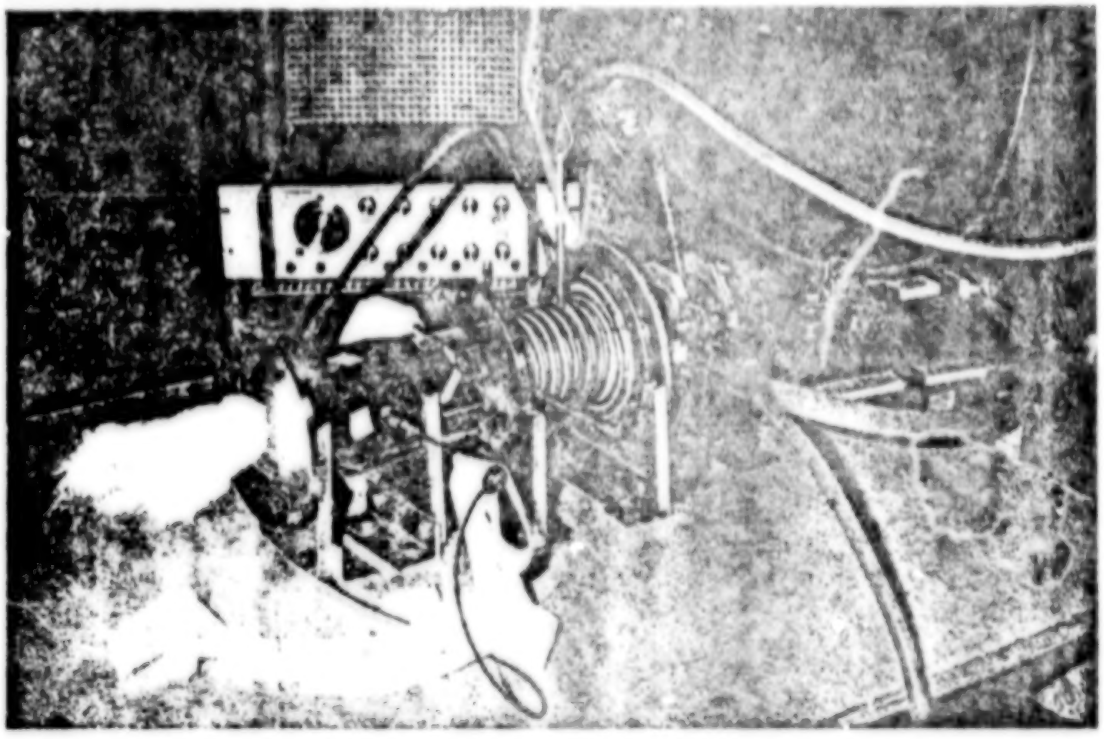
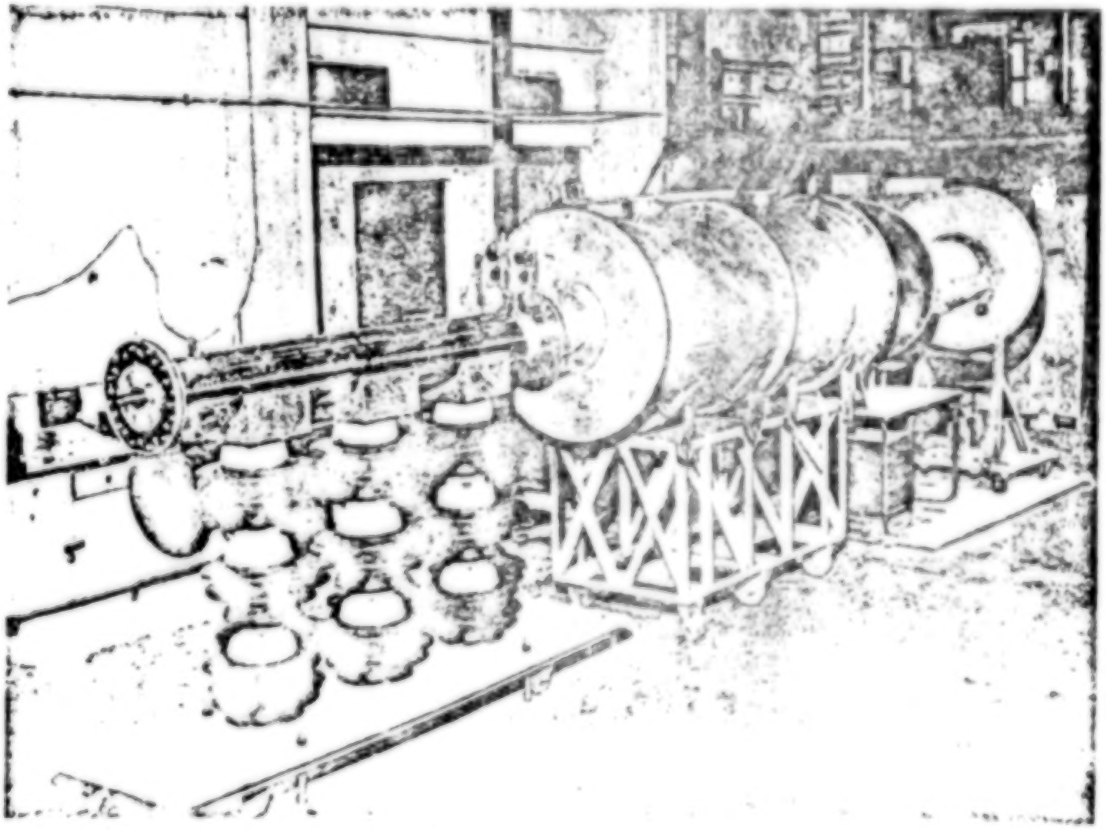


Above: Plasma torch made at BARC. it generates argon plasma at a temperature higher than 15000 K. The unit can give average flame temperatures of 3000 K. The plasma jet has been set up primarily for conducting studies on Magnetohydrodynamic plasmas and materials being developed for MHD power generation at BARC. Below: Million Volt, 150 kiloampere, 30 nanoseconds power generator, being developed at the Plasma Physics Section of the Bhabha Atomic Research Centre, Trombay, for experiments with relativistic electron beam.



Atomic Energy Establishments in India

GENERAL SURVEY

ATOMIC energy has never been entirely free from the pulls and pressures of realpolitik, and India's nuclear effort has had to contend with such influences increasingly. The past year witnessed the same kind of unfavourable manoeuvres which are becoming a familiar experience of most developing countries pursuing an independent nuclear policy. India however is among the fortunate few who have sustained their nuclear programmes largely on their own, and consequently pressures have only gone to strengthen their own efforts further. As the Prime Minister put it emphatically in the Rajya Sabha in July 1978: "We are wedded to the use of nuclear energy for peaceful purposes . . .and we are going on with it whatever any country might say."

The atomic energy programme has continued to move in the light of this policy, and has been contributing to the development of the country's technological prowess. An advanced science and technology, drawing upon a still developing industrial base cannot of course be expected to have a smooth course towards its goal, and India's nuclear efforts have had to face difficulties in this regard. However, though it has not moved exactly along the path charted in the early years, the programme has maintained a steady tempo, building up in the process invaluable assets of skilled personnel, nuclear infrastructure and advanced technology. The past year witnessed a continuation of this overall development process. In this brief report an attempt is made to present a broad view of developments in the wide-ranging activities of the Department covering, among other things, atomic minerals, nuclear fuel, power, research and development, and applications of atomic energy in the fields of agriculture, industry, medicine and other areas.

Nuclear Power

Taking nuclear power first, the last few years have seen considerable improvements in the capacity and capability of Indian industry to meet the needs of the Department in the matter of large and sophisticated nuclear components. A high level of technology and skills has been attained by the industry as a consequence of the Department sharing its knowhow and experience with it. This collaboration has resulted not only in the manufacture of many complex nuclear components for the first time in the country, but also in the improvement in quality of even conventional components such as pipes and tube fittings, valves, pumps, cranes etc. manufactured by the industry. The Department has also helped to reduce manufacturing delays by standardising designs of some of the equipment of power plants.

There are three atomic power stations, each with 2 units, under construction near Kota in Rajasthan, Kalpakkam in Tamil Nadu and at Narora in Uttar Pradesh. One station, at Tarapur in

Maharashtra, has been in operation since October 1969, and one unit of the Rajasthan Atomic Power Station has been operating since 1973. The Tarapur Station is the only station operating on enriched uranium, which is imported from the United States. The Station has two units of around 200 MWe each. The developments in this station during the year are along the following lines: In the first 11 months of the year, the Tarapur Station generated around 2178 million units, registering a capacity factor of 64.7 per cent. It supplied 1072 million units of power to Maharashtra, and 946 million units to Gujarat during the period. This output is 110 per cent of the generation target adopted for the period by the Central Electricity Authority. Unit I of the Station was operated at 170 MWe to conserve the available fuel in view of the uncertainties of supply of enriched uranium from the USA, and also due to shortage of space for storing spent fuel. Unit II of the Station was operated continuously at 90 per cent of its capacity, bringing its on-line availability for the first 8 months of the year to 91.11 per cent, and capacity factor to 78.1 per cent.

At the Rajasthan Station, Unit I was resynchronised to the grid on September 20, 1978 after having been shut down during the period April 1, 1978-September 19, 1978. The power output was brought up to 185 MWe and efforts are on to reach full capacity before March 1979. Unit II of this Station is ready for its operations preparatory to taking in heavy water for the final stages of commissioning. At the Madras and the Narora Atomic Power Projects, civil works and work relating to manufacture of nuclear equipment are progressing.

Nuclear Fuel Complex

A noteworthy development at the Nuclear Fuel Complex at Hyderabad during the year is the commissioning of the Stainless Steel Tube Plant in April 1978. It produced about 35 tonnes of Seamless Tubes, valued at approx. Rs. 29 lakhs upto December 1978. Another plant in hand at the Complex is the Ball Bearing Tube Plant, which is expected to start production in April 1979. The plant has a capacity of 21,000 tonnes of ball bearing and 3,000 tonnes of oil drill pipes per annum.

The major responsibility of the NFC is fabrication of fuel elements for power reactors of the pressurised heavy water type at the Kota, Kalpakkam and Narora stations, and fabrication of fuel for the Tarapur Atomic Power Station from enriched uranium hexafluoride supplied by the USA. Its enriched uranium oxide plant however could not work to capacity during the year for want of the uranium hexafluoride in the required quantities.

Heavy Water

There are four heavy water plants under the programme, located at Baroda, Kota, Talcher and Tuticorin. The Baroda plant is undergoing repairs consequent to its being damaged in an explosion on December 3, 1977, and is expected to commence production by end of 1979. The Tuticorin Heavy Water Plant, which commenced production in July 1978, was not operating for some time due to the shutdown of the ammonia plant of the SPIC's fertilizer unit. It commenced production again in January 1979, but has had to be shutdown again owing to some technical problems with SPIC'S ammonia plant. The Talcher plant is expected to become operational by end of 1979; and commissioning work on the Kota plant is expected to

start in December 1979, with the plant likely to go on stream in the middle of 1980.

Reactor Research Centre

India's long term nuclear power strategy centres around the breeder reactor, which will be using thorium. As part of this long term plan, a Reactor Research Centre has been set up at Kalpakkam near Madras for carrying out research and development work on all aspects of the breeder technology. A Fast Breeder Test Reactor and associated facilities are coming up at the Centre. The reactor is being built in collaboration with France, with the major components fabricated indigenously. At present, the civil works for the reactor building, and the buildings to house other units such as the turbine, steam generator etc. have been completed and the reactor vessel has been fabricated. Other important components are under fabrication.

Atomic Minerals

Locating sources of uranium and other atomic minerals in different parts of the country is a major activity of the Atomic Minerals Division of the Department. Survey and prospecting work, including core drilling and development mining for uranium, thorium, columbium, tantalum and beryllium minerals is done by the Division continuously. During the last one year, around 21,500 sq. km. were covered in different parts of the country in reconnaissance surveys for uranium and other atomic minerals. Special mention may also be made of investigations carried out in the thermal spring areas of Bakreshwar, Tantoli, Nunbil, Tantleswar, Surajkund, Pulsiri and Barapalasi in West Bengal and Bihar for helium gas.

Research and Development

Research and development work is pursued at the Bhabha Atomic Research Centre and in three aided institutions: the Tata Institute of Fundamental Research, Bombay, the Saha Institute of Nuclear Physics, Calcutta, and the Tata Memorial Centre, Bombay. The last three are administratively under the control of the Department. Activities in the first three institutions cover a wide and diverse range of disciplines, both in the areas of basic research and applied research; the Tata Memorial Centre concerns itself mainly with research on cancer, and its treatment.

An important development in recent years is the commissioning of the Variable Energy Cyclotron at Calcutta, a research facility built and being managed by BARC. In July 1978, an external beam of 30 MeV alphas was first obtained at the Cyclotron, an internal beam of upto 50 MeV alphas rays having been obtained the previous year. A computer, IRIS-80, was received from France and commissioned at the Cyclotron during the year. The User's Committee of the VEC has started examining programmes of work to be undertaken when the machine is opened to outsiders. Though work is proceeding apace in this direction, the operation of the Cyclotron is being seriously hampered by the bad power situation in Calcutta. A 2 MVA diesel generator is likely to be installed by the middle of 1979 to ease the situation.

Another research facility, a 100 MW thermal reactor, R-5, wholly of Indian design, is at present under construction at Trombay. Currently, civil works on the reactor building and associated facilities are nearing completion, and the reactor components such as the reactor vessel, coolant channel assembly, end shield, annular shield, fuelling machine etc. are being fabricated.

Among other interesting activities at

BARC is the MHD Power Generation Project. The MHD method pertains to the direct conversion of thermal energy to electrical power. This technology is expected to improve the thermal efficiency of fossil fired power plants from the present 30-40 per cent to 50 per cent, and even higher. The project is being jointly executed by the BARC and the Bharat Heavy Electricals Ltd., Trichi, with the design of the MHD generator, magnet and control system for the plant coming from BARC. A small 10 kw MHD generator of Indian design and fabrication will be tested in Moscow under the Indo-Soviet Cooperation programme.

As part of the work in plasma physics at the Centre, a plasma cutting torch was developed during 1977-78. During the past year, the know-how for this torch was transferred to a firm in Bangalore, which is now offering the units commercially. Another highlight of work in this field is the development of a portable local vacuum electron beam welding machine. The machine was completed during the past year after development work extending over three years. The machine is normally rated at 10 kV voltage and is capable of doing circular welds on large components. As only local vacuum is necessary, large and expensive vacuum chambers are not needed in this case.

Radioisotopes

BARC prepares a large variety of isotope products which have wide applications in agriculture, industry, medicine, and many other areas. During the year, the Centre processed and supplied over 32,000 consignments of 50 radiopharmaceuticals to hospitals and medical research institutions in the country. Around 200,000 patient investigations are estimated to have been carried out through such radiopharmaceuticals and services. To enhance the capacity for radiopharmaceutical development and production, a radiopharmaceutical laboratory is being built at Vashi, near Bombay.

There have also been some important developments in the area of industrial applications. A Panoramic Batch Irradiator (PANBIT), built by BARC, was successfully commissioned at a private plywood firm at Baliapatam, Kerala, during the year. The unit at present houses 50,000Cis of cobalt-60. A similar unit, also supplied by BARC, is being installed at the Pasar Jumat Research Centre, Jakarta, Indonesia. Units are being fabricated for the Chitra Thirunal Medical Centre, Trivandrum, and the Nuclear Research Laboratory, Srinagar.

Besides these activities, there has been some good work pertaining to sewage treatment. Design and engineering details of a Sewage Sludge Research Irradiator (SSRI) for hygienisation of sewage sludge are being worked out. The irradiator will treat about 100 M^3 of sewage sludge per day with gamma radiation from cobalt 60 of an installed capacity of about 300,000 Cis.

Among other applications during the year is the use of the radiotracer technique for locating minute leaks in the 140 km. long Koyali-Viramgam oil pipeline. The use of the technique saved at least 6 months time in the testing and commissioning of the pipeline. Besides, the inspection was carried out at less than one-tenth of the cost of the conventional technique. The radiotracer technique was also used to examine the nature of a geological fault at the Lakya dam site of the Kudremukh Iron Ore Project in Karnataka. The dam will store iron ore waste, and therefore it was essential to know whether a fissure noticed in it was connected to the river flow. The investigations established that

the fissure was not connected to the river flow but to two points at which seepage had occurred through an underground reservoir. The project authorities were helped by this finding to take remedial measures without loss of project time.

The isotope activity also included production of agro-chemicals labelled with isotopes. These labelled agro-chemicals were supplied to the different agricultural institutions in the country and also exported to some neighbouring countries.

Biology & Agriculture

Research work in the field of Biology and Agriculture has helped in the development of a number of high yielding, disease-resistant mutants of a variety of crops. During the year, over 2,500 tonnes of seeds of Trombay Groundnut cultivars TG-1, TG-3 and TG-17 were produced at Trombay in the kharif season under the improved seed multiplication programme of the Vanaspati Manufacturers Association of India. These cultivars are now included in trials in the States of Gujarat, Maharashtra, Karnataka, Andhra Pradesh and Madhya Pradesh. Other noteworthy mutants developed at BARC are Trombay Tur cultures (TT-4, TT-5 and TT-6), Trombay Rice culture (TR-17), wheat mutant (TW-1), and jute, and cane mutants. All these cultures are under trial.

Desalination

Desalination is another area of work which the BARC has been pursuing with good results. It has already two pilot plants: a Multi-Stage Flash Distilation Plant, and a Vertical Tube Evaporator Plant in operation at Trombay, and, on the basis of experience with these plants, it is designing a combined VTE-MSF pilot plant of 250 M^3/day capacity. It has submitted a feasibility report to the Government of Gujarat for setting up a 4500 M^3/day MSF plant at Kandla, and also provided technical consultancy service to the BHEL, enabling it to offer to build 1200 M^3/day and 2400 M^3/day desalination plants in Tanzania. A similar consultancy service has been offered by BARC for setting up an 1800 M^3/day MSF desalination plant at Mithapur (Gujarat).

Besides these assignments, the Centre is engaged in designing a 2 tonne/day flash type, and 3 tonne/day vapour compress type ship-borne desalination plants. A 6 M^3/day reverse osmosis brackish water desalination plant has been installed at the VEC in Calcutta.

The BARC is also operating a plant for elemental phosphorus production and is at present preparing project reports for two 2,500 tonne/year plants. Studies are also being carried on on the utilisation of byproducts from the phosphorus plant, and integrated schemes for production of fertilizers. It has been found that there is considerable demand from entrepreneurs for the technical knowhow related to elemental phosphorus production.

Tata Institute of Fundamental Research

The work at the Tata Institute of Fundamental Research is diverse and wide ranging. It has been working on, among other things, establishing the relationship between radon content in the monsoon air mass and monsoon activity, a new concept for creating groundwater reservoirs suitable for the Indian environment, and on work relating to measurements of methane in groundwater, with a view to observing their utility in oil exploration.

At the Radio Astronomy Centre of the TIFR at Ooty, a Synthesis Radio Telescope (OSRT) is under construction. The system will comprise 13 small low cost antennas spread around the Ooty Radio Telescope at distances upto 10 km. When completed, the OSRT will be one of the largest synthesis radio telescopes in the world, and the only one operating at metre wavelengths.

Tata Memorial Centre

At the Tata Memorial Centre, Bombay, a new development has been work in the area of microsurgery, a new advance in surgical technique taken up for the first time during the year. The Hospital will be commissioning a special microsurgical theatre and ward during the latter half of 1979.

Public Sector Undertakings

The Department runs three public sector undertakings: the Uranium Corporation of India Ltd. (UCIL), the Electronics Corporation of India Ltd. (ECIL), and the Indian Rare Earths Ltd. (IRE). At UCIL, the commissioning of stage II of the uranium mine at Jaduguda has opened up more levels, and consequently more number of working faces. The grade of ore at the deeper levels is also likely to be higher. Production of uranium concentrates is therefore expected to increase during the year if the power supply position at Jaduguda improves. The position of ECIL has not been a happy one; during 1977-78, it incurred a loss of Rs. 105.42 lakhs. The unfavourable performance is attributed mainly to the provision of liability made for implementation of revised pay scales for the period from January 1, 1977 to March 31, 1978, and adjustments made for some other items of expenditure pertaining to the earlier years. The Indian Rare Earths Ltd., has had another good year. Its sales turnover during 1978-79 is expected to be of the order of Rs. 9.6 crores, of which exports account for approx. Rs. 4.6 crores. The figures for 1977-78 are Rs 8.7 crores and Rs. 4.9 crores. The Company's Orissa Sands Complex (OSCOM Project) near Chatrapur, Orissa, is progressing satisfactorily.

International Relations

On the world scene, India continues to play a prominent part in promoting the use of nuclear energy for peaceful purposes. During the year it was again designated on the Board of Governors of the International Atomic Energy Agency, the 22nd year in succession since the formation of the IAEA.

Under the Technical Assistance Programme of the IAEA, and under different bilateral collaboration agreements, India continued to provide expertise, and training in its establishments to scientists from other countries.

India signed new agreements for collaboration in the peaceful uses of atomic energy with the USSR, Yugoslavia and Libya during the year.

NUCLEAR POWER

The performance of the atomic power station at Tarapur, and progress of work at the power projects at Rana pratapsagar, Kalpakkam, and Narora are discussed, in addition to work at the supporting units of the power programme, *viz* the Nuclear Fuel Complex at Hyderabad, the Heavy Water Plants, and the Atomic Minerals Division. The Atomic Power Authority manages the Tarapur Station and looks after the commercial aspects of Unit I of the Rajasthan Station. The power projects are being built by the Power Projects Engineering Division.

Atomic Power Authority

Tarapur Atomic Power Station

DURING the first eleven months of the year, the Station generated 2178 million kwh, registering a capacity factor of 64.7 per cent. The station sent out around 1072 million units of power to Maharashtra, and around 946 million units to Gujarat. This is 110 per cent of the generation target as adopted for this period by the Central Electricity Authority.

The Station has so far completed 10 refuelling outages. Unit I was shut down for its fifth refuelling on June 20, 1978 and synchronised to grid on August 27, 1978. Refuelling was completed in a record time of 68 days-the shortest time so far. The Unit's performance improved considerably during the year after its fifth refuelling outage. Its on-line availability and the capacity factor were 71% and 51.3% respectively. The Unit's output has been restricted to about 170 MWe after the 5th refuelling outage, and to about 140 MWe since Feb. 79 to conserve the available fuel in view of the uncertainty of supplies of enriched uranium from the USA, and also due to the limited storage space available in the spent fuel storage pools.

Unit II was continuously operated at over 90 per cent of capacity. The on-line availability for the first eleven months of the year was 91.8 per cent, with a capacity factor of 78.1 per cent. Unit II was taken out for refuelling in March 1979.

Fuel management for both the Units is being done internally by special Computer Codes and from know-how built up by BARC. This service was earlier obtained from the reactor suppliers, General Electric Co., USA. The operation of both the reactors with the fuel management service rendered by BARC, has been satisfactory.

The current U. S. position on Tarapur prevents the Department from reprocessing the spent fuel from the Station's reactors and consequently, the spent fuel storage pools have got filled up beyond their designed capacity. At present, the pools are being cleaned to accommodate high density fuel racks, the design for which is being finalised. In the interim, some indigenously fabricated racks have been added.

Commercial Aspects

The revenue for the year is expected to provide a satisfactory surplus after meeting all operating expenses, interest depreciation and appropriations to statutory reserves. The surplus for 1977-78 was around Rs 9 crores.

The performance of the 220 KV switchyard at Tarapur, which is now under the technical control of the Tarapur Atomic Power Station, has been satisfactory.

Power Projects Engineering Division

Rajasthan Atomic Power Station

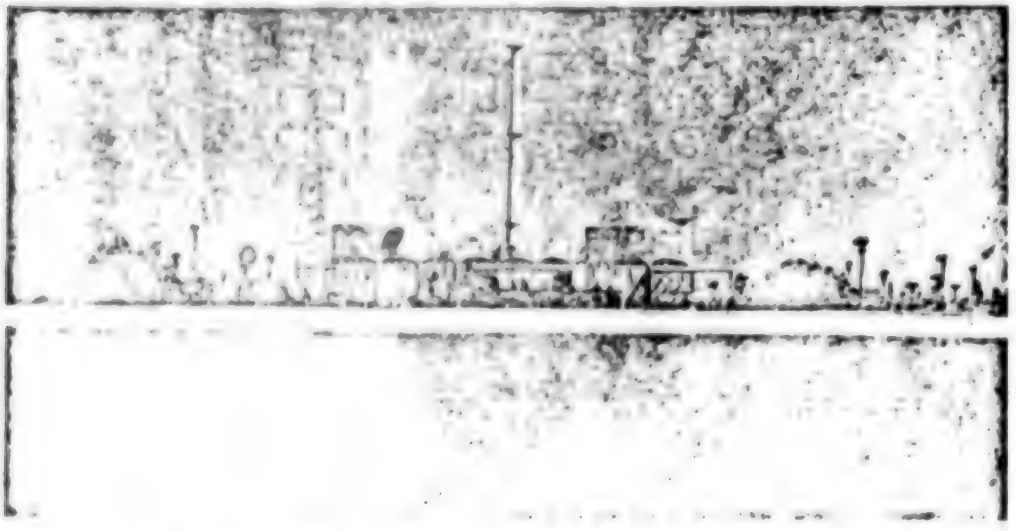
Unit I, which had been shut down for maintenance, was resynchronised to the grid on September 20, 1978. The unit has been generating around 185 MWe since then, and is expected to reach full power before end March 1979. The Unit generated in all around 477 million units during the year.

Unit II is almost complete, it is ready for all operations preparatory to taking in heavy water for the final stages of commissioning. From experience gained on Unit I, certain design changes and system modifications are being carried out on Unit II in the interim, before heavy water becomes available.

Madras Atomic Power Project

In Unit I, construction work as well as installation of equipment has been completed in all areas except those relating to fuel handling and instrumentation. In the fuel handling system, equipment has been installed in the fuel transfer room, the fuelling machine carriages have been assembled, and spent fuel equipment positioned. About 70 per cent of the work of installing instrumentation has been completed. The major plant piping works have been completed and the systems are in different stages of testing and commissioning. The turbo-generator, along with auxiliary systems and the condenser has been installed. Take over, testing and commissioning of individual systems is on. Except for some minor items, all electrical works have been completed, the diesal generators have been commissioned, load tested and synchronised to the grid.

Overall view, from west side, of the Madras Atomic Power Station, Kalpakkam.



In Unit II, most of the civil works have been completed. On the equipment manufacturing side, fabrication of coolant tubes is on. The calandria tubing installation work is nearing completion All the eight boilers and thermal shields have been installed; the end-shields have been positioned. About 48 per cent of main plant piping work, 60 per cent of turbo-generator installation work, 70 per cent of work on the sea water system, and 25 per cent of electrical work have been completed. The start-up transformer and all motor control centres have been installed.

Narora Atomic Power Project

About 40 per cent of the construction work on the building for reactor No. 1 has been completed, and construction of calandria vault has started. Work on the perimeter walls of Reactor Buildings I & II is on.

Piling work has been completed in all respects for both Unit I and II. Work is on on the Turbine Building and the Service Building. Parallel to the civil works, the multifarious jobs of preparing plant layouts, designs for equipment and indenting etc. are going on.

Nuclear Fuel Complex

The work at the Nuclear Fuel Complex, Hyderabad, is organised in two Groups: (i) the Fuels Group and (ii) the Tubes Group.

The Fuels Group has the responsibility for meeting the Fuel and Zircaloy hardware requirements of the nuclear power reactors. The following plants are operated under this Group: (1) Zirconium Oxide Plant (2) Zirconium Sponge Plant (3) Zircaloy Fabrication Plant (4) Uranium Oxide Plant (5) Enriched Uranium Oxide Plant (6) Fuel Fabrication Plant (7) Fast Breeder Test Reactor Component Facility.

A Special Materials Plant, which makes ultrapure elements and components for the electronics industry, also forms part of the Fuels Group. There is, in addition, an operating Titanium Pilot Plant.

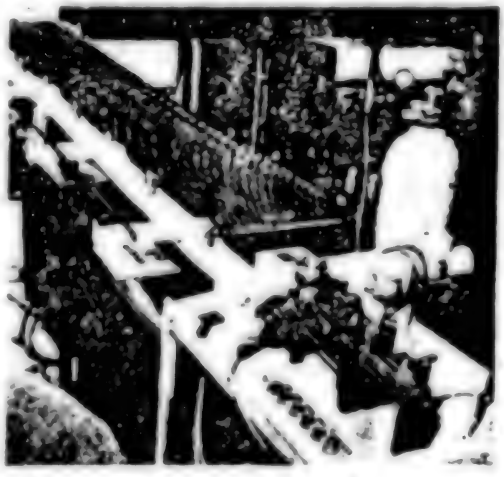
The Tubes Group comprises (i) Extrusion & Piercing Presses (ii) a Seamless Stainless Steel Tube Plant and (iii) a Ball Bearing Tube Plant.

During the year, the NFC worked to supply the following items:

(i) The entire requirement of Calandria Tubes, and part requirement of the Coolant Tubes for the Madras Atomic Power Project-II, (ii) The entire requirement of inner and outer flow tubes for the Madras Atomic Power Project-I, (iii) Reload fuel requirements for the Tarapur and Rajasthan Atomic Power Stations, (iv) part of the initial core requirements for the Madras Atomic Power Project-I, and (v) components for the R-5 reactor, like beam hole tubes, dump manifolds, rods, sheets etc.

The following items, fabricated indigenously, were commissioned during the year: (i) A Vacuum Annealing

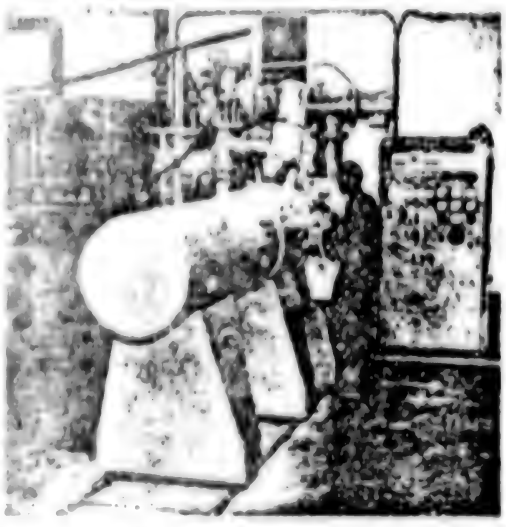
Nuclear Fuel Complex, Hyderabad. Indigenously made inert gas welding machine for welding zircaloy fuel pins. This unit would cost Rs. 25 lakhs, if imported.



Furnace for Zircaloy Components, costing approx Rs 18 lakhs, (ii) Electron Beam Welding Unit for welding Zircaloy-2 electrodes, costing approx Rs 8.5 lakhs, (iii) A TIG Welding Machine for welding TAPS Fuel Elements, costing approx Rs 0.8 lakhs. The manufacture of these items in the country saved foreign exchange to the tune of Rs 60 lakhs.

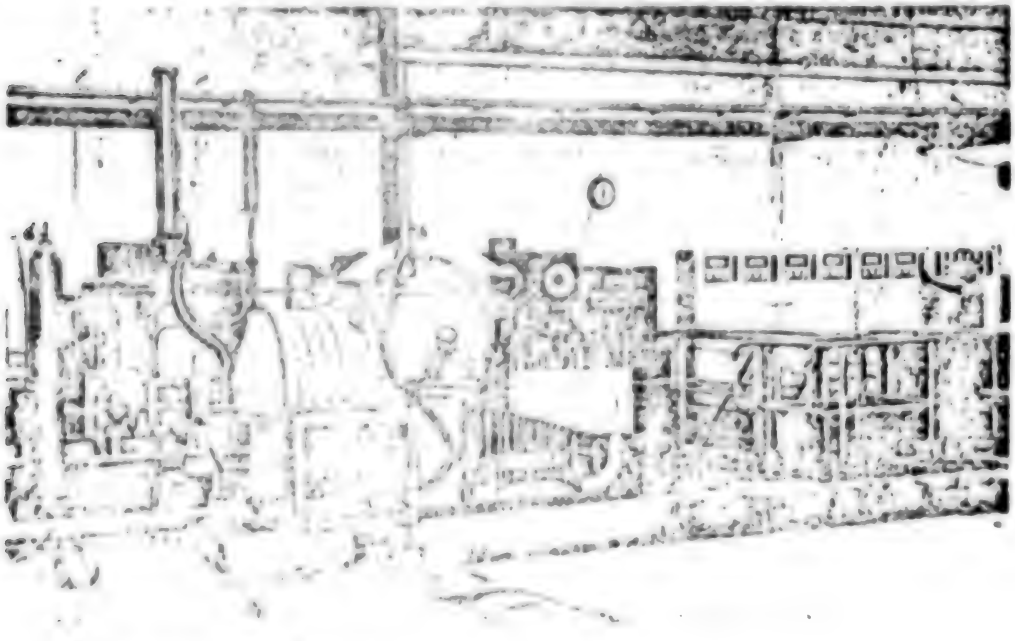
The following equipments are under fabrication/commissioning: (i) 150 kw self-resistance sintering furnace for production of high purity tantalum at the Special Materials Plant and (ii) Walking beam sintering furnace at the Ceramic Fuel Fabrication Plant (indigenous manufacture of these items will save foreign exchange to the tune of Rs 30 lakhs).

The Enriched Uranium Oxide Plant could not work at full capacity for want of enriched uranium hexafluoride (imported from the USA) in the required quantities. At the Enriched Fuel Fabrication Plant, an improved design of fuel pellets and pins for the Tarapur



Nuclear Fuel Complex, Hyderabad. Indigenously fabricated 25 kilowatt electron beam welding unit for welding zircaloy at the Zircaloy Fabrication Plant of the Complex. This unit would cost Rs. 30 lakhs, if imported.

Indigenously fabricated vacuum annealing furnace, at the Zircaloy Fabrication Plant of the Nuclear Fuel Complex, Hyderabad. This 1.2 metres diameter, 9.4 metres deep unit would cost Rs. 35 lakhs, if imported



Atomic Power Station fuel has been finalised, and prototype pellets and sample fuel pins have been made. At the Uranium Oxide Plant, trials are on for making UO_2 powder by an alternative route.

At the Special Materials Plant, sales are expected to go up from Rs. 15 lakhs in 1977-78 to Rs. 25 lakhs in 1978-79. A 180 kw self-resistance furnace (mentioned earlier) made indigenously, will be commissioned shortly.

The Plant has developed a process for producing high purity magnesium and is trying to interest entreprenuers to exploit the process.

The Titanium Plant produced 2,488 kgs. of pure titanium tetrachloride, of which it sold 2,224 kgs.

Trials are being conducted in the Zirconium Sponge Plant for recovery of zirconium values from the zirconium tetrachloride accumulated in the Fuel Reprocessing Plant's ducts.

The value of production achieved in the Fuels Group till end December 1978 works out to around Rs. 506 lakhs, and sales revenue to Rs. 309 lakhs.

The extrusion press is being modified and work is on to erect and commission other equipment *i. e.* piercing press, horizontal induction furnaces (3 in number), and vertical furnaces (4 in number).

The Stainless Steel Tube Plant (SSTP), which has an installed capacity of 2,000 tonnes per annum, went into production in April 1978. Some initial teething troubles are being sorted out progressively. About 35 tonnes of Seamless Tubes, valued at approx Rs. 29 lakhs, have been produced and supplied to customers upto December 1978. A target of 100,000 metres of Pilger tube has been set for 1978-79. It has been noticed that although the Project envisaged production of tubes of size 16 mm OD and above, the major part of the demand is for tubes of smaller sizes. A draw bench for producing the smaller tube is expected to be set up by July 1979.

The Ball Bearing Tube Plant (BBTP), with a capacity to produce 21,000 tonnes of ball bearing tubes and 3,000 tonnes of oil drill pipes per annum is under erection. The major civil works are over and the installation of the two major items of equipment *viz.* the Pilger Mills and Annealing Furnaces is expected to be completed shortly. Though the project as a whole is expected to be completed only by August/ September 1979, production of Ball Bearing Tubes may commence in April 1979 itself.

Heavy Water Projects

Heavy Water Project (Baroda)

The damage caused by the accident on December 3, 1977 has been assessed and work on revamping the plant is in progress. The plant is expected to be back in production in December 1979.

Heavy Water Project (Tuticorin)

Production of heavy water started in this plant in July 1978. The operation of the plant was however affected during the year due to interruption in the supply of synthesis gas from the ammonia plant of SPIC's fertiliser unit, and due to power trips and wide fluctuations of voltage in power supply.

Owing to some technical problems leading to the shutdown of the ammonia plant of the fertiliser complex of SPIC, the Heavy Water Plant had to be shutdown. It is expected to start operation as soon as the ammonia plant starts working.

Heavy Water Project (Talcher)
Pre-commissioning tests of the main plant are in progress. Piping and instrumentation work are in the last phase of completion. Commissioning work will commence immediately after mechanical completion of the plant, which is expected by August, 1979. The plant is likely to become operational by the end of 1979.

Heavy Water Project (Kota)
The mechanical completion of the plant is expected by end of December, 1979. Testing and commissioning of the main production units are scheduled to commence soon thereafter and the plant is expected to go on stream by the middle of 1980.

Atomic Minerals Division

Underground Exploration for Uranium. At Bodal in the Rajnandgaon district of Madhya Pradesh, the main vertical shaft being sunk for investigating uranium ore zones attained a depth of 46.50m. The presence of ore zone between 28.90 m and 43.8 m, with ore grade ranging from 0.083 per cent to 0.127 per cent eU_3O_8, and thickness of 1.50 m to 3.30 m depths, has been indicated. The two adits at Jajawal in the Sarguja district of Madhya Pradesh have attained lengths of 56.70 m and 26.50m respectively. The adits are expected to meet the ore zone at an approximate distance of 165m. At Astotha and Khya in the Hamirpur district of Himachal Pradesh, two adits have progressed to lengths of 30 m and 15 m respectively. The adit at Astotha has intercepted the ore horizon in the form of lenses. Ore zones between 12 and 16.5 m distance, with thickness of 0.45 to 4.5 m, and grade from 0.06 per cent

Aerial survey equipment developed by the Atomic Minerals Division. The racks on the right show the electronic console of the gamma-ray spectrometer, digital data acquisition and recording system, fabricated at the Division.

to 0.10 per cent of eU_3O_8, have been indicated.

Survey and Exploration. A total of 21,340 sq. km. have been covered in different parts of the country by reconnaissance survey for uranium, thorium and columbium-tantalum bearing minerals.

This reconnaissance included surveys carried out over an aggregate coastal length of 47.57 km, covering an area of 3,784 06 hectares in Cannanore district, Kerala; Kanyakumari and the Tirunelvelli district, Tamil Nadu, and the Krishna, Guntur and Visakhapatnam districts of Andhra Pradesh.

Occurrence of uraniferous quartz-pebble-conglomerate in Walkunji-Someswara area in South Kanara district, Karnataka, has been noticed intermittently over a total strike length of 2 km. Similar finds at Gudimane, about 65 km. north-west of Walkunji, have also been found to be radioactive.

Significant radioactivity in greyish sandstone was noted in middle upper Siwalik formations in Sibal in the Hamirpur district of Himachal Pradesh.

Interesting anomalous radioactivity due to uranium has been noticed in the granite-gneiss in Asnangiri, Garo Hills district, Meghalaya, the granite at Bannerghetta, near Bangalore, Karnataka, and in the Annavaram area, Nellore district, Andhra Pradesh. Similar radioactivity anomalies have been noticed in the Tura sandstones of the Garo Hills, the Mahadek sandstones of the Khasi Hills district, Meghalaya, in the Quartz-Veins in Daling phyllits in the Jagdumb area of Sikkim, and in the Pambu-Khola area of Darjeeling district, West Bengal.

Recovery and production of columbite-tantalite yielded over 11.25 tonnes of the minerals during the year.

Thorium Investigations. Estimation of monazite and other heavy minerals in the dunes and adjoining areas of the 71 acre plot near the Zircon and Rutile plants of the Indian Rare Earths Ltd. near Manavalakurichi, Tamil Nadu was completed on a crash basis and a reserve of 5,24, 580 tonnes of ilmenite, 22,550 tonnes of rutile, 52,430 tonnes of monazite and 41,720 tonnes of zircon was estimated. Experiments resulted in upgrading the total heavy minerals content of 31.4 per cent grade available in the area to 73 per cent grade. A preconcentrator plant will thus be useful in exploiting the low grade sand deposit for the industry in the West Coast where a minimum cut-off grade for heavy minerals content is fixed around 70 per cent.

The reserves of heavy minerals in the Midalam-Ilanjam sand deposits in Kanyakumari district, Tamil Nadu, have been estimated at 179,133 tonnes of ilmenite, 14,942 tonnes of zircon, 10,124 tonnes of monazite and 6,748 tonnes of rutile.

Special Investigations. Investigations were carried out in the thermal spring areas of Bakreshwar, Tantoli, Nunbil, Tantleswar, Surajkund, Pulsiri and Barapalasi in West Bengal and Bihar for assessing the potential of helium gas. Helium content in the gas samples assayed 0.31 to 1.34 per cent, with an average of 0.5 per cent.

A gas chromatographic laboratory has been set up at Calcutta as a part of the helium project for estimating helium, argon etc. in the gas collected from various field areas. A pilot semipurification plant has been commissioned at Bakreshwar.

Collaboration with other organisations. The Division continued to collaborate in scientific investigations with State Government Departments, Public Sector Undertakings, Universities etc. Under this programme, bore holes drilled in different parts of the country by the various agencies were examined for radioactivity. Technical assistance by way of analytical facilities, and training of research scholars was provided to the Geological Survey of India, the Universities of Aligarh, Rajasthan, Osmania, Science College, Hyderabad, Rajindra Medical College, Ranchi, Sikkim Mining Corporation, Rangpo, Rajasthan State Mines and Minerals Ltd., and the Reactor Research Centre, Kalpakkam.

Collaboration with other countries, and international projects. Work under the International Atomic Energy Agency's Research Contract on 'Study of factors controlling formation of sandstone type uranium deposits in India' is being pursued.

Two Vietnamese and one Gambian scientist were given training under the Technical and Economic Cooperation programmes, and the United Nations Development Programme respectively.

RESEARCH AND DEVELOPMENT

Besides the Bhabha Atomic Research Centre at Trombay, units discussed here include the Reactor Research Centre at Kalpakkam, and the three aided institutions administratively responsible to the Department, *viz* the Tata Institute of Fundamental Research, Bombay, the Saha Institute of Nuclear Physics, Calcutta and the Tata Memorial Centre, Bombay The Tata Memorial Centre comprises two institutions: the Tata Memorial Hospital and the Cancer Research Institute.

Bhabha Atomic Research Centre

Nuclear Physics/Solid State Physics

Experiments were conducted in search of superheavy elements in the monazite sands of South India with an improved K X-ray fluorescence technique. No evidence of the presence of superheavy elements was found above the detection limit of 2 ppm, reached by this method.

In Solid State Physics, many interesting phase transformations in solids are being studied. The high pressure alpha-to-omega phase transformation in titanium, zirconium, and hafnium is being investigated. Several new ferroelastic materials have been discovered, *e.g.* barium chloride dihydrate and potassium chlorate. A new class of materials in ferroics, called 'gyrotropics', has also been identified; these materials reverse the sign of optical rotation on application of pressure.

Several molecules of pharmacological and biological importance were also studied. A new experimental programme was initiated to study the structures of large biological molecules like proteins.

High Altitude Research

In High Altitude Research, an experiment for the detection of optical pulses from primordial black hole explosions has been set up at the High Altitude Research Laboratory, Gulmarg and the Nuclear Research Laboratory, Srinagar. The experiment will look for events coincident within 1 millisecond at the two stations. Observations of such coincident events will shed new light on the early history of the universe and help in reaching some conclusions on the various cosmological theories.

A seismograph/microbarograph system was installed at Gulmarg to study the background seismic and microbarographic activity. This system will be used in association with the Gauribidanur Seismic Array to detect underground and atmospheric nuclear explosions. The seismic data from the system will be used for a correlative study of geophysical and seismic activity, and for the possible identification of earthquake precursors.

Variable Energy Cyclotron (VEC)

The Variable Energy Cyclotron project located at Calcutta has now been

commissioned for the external beam.

An internal beam upto 50 MeV alpha rays was obtained in June 1977. An external beam of 30 MeV alphas was first obtained on July 8, 1978.

Substantial progress was made in the external beam system. The switching magnet-1, which will allow the 3 high intensity beam channels to be used, has been installed and the design for the second switching magnet is ready. The machined steel core of the analysing magnet is ready and the coils for that magnet and the vacuum chamber are under fabrication.

Work on building the attached research facilities has been stepped up. An IRIS-80 computer is being installed at the facility.

Operation of the cyclotron has been seriously affected by the unusually bad power situation in Calcutta. The commissioning of the external beam was possible only by work at night over a period of 5 months. Normally, the cyclotron should be operated round the clock. Unless this situation is achieved it is difficult to start any meaningful experiment using the cyclotron beam. As a result, the facility cannot be opened to users from various institutes and university departments. Since there is no guarantee of uninterrupted power from the grid, it as been decided to install a 2 MVA diesel generator for the operation of the cyclotron.

The VEC Users Committee is examining the programme of work to be undertaken when the machine is opened to the users.

Plasma Physics

At Tiruchirapalli in Tamil Nadu, an MHD power generation project is being jointly executed by BARC and Bharat Heavy Electricals Ltd. The civil works of this project, including work on the laboratory buildings, is now nearing completion. BARC is responsible for designing the MHD generator, magnet and control system for the plant. The conceptual designs and fabrication drawings are ready and material and equipment are being procured. A small 10 kw MHD generator, designed and fabricated indigenously, will be tested in Moscow under the Indo-Soviet cooperation programme. Besides work on the project, a research programme relating to the physical properties of MHD working fuels, plasma and gas dynamics, boundary layer and heat temperature materials and plasma diagnostics, is being pursued as part of this activity. The transfer of knowhow for the 100 kilowatt plasma cutting torch to a firm in Bangalore has been completed and the units are now being commercially marketed by the firm. Another technology in the same line—plasma spray technology, developed at the Centre, is also being transferred.

A Relativistic Electron Beam (REB) system has been designed and is under development. Development work in this area is oriented towards (a) generation and characterisation of high current pulsed electron beams, (b) propagation of these beams in vacuum, neutral gases and plasma and (c) generating and heating of plasma.

Electron Beam Welding Technology. A portable local vaccum electron beam welding machine, under development for the past three years, was completed and is being tested. This machine is nominally rated at 10 kV voltage and is capable of carrying out circular welds on large components. Only local vacuum is necessary, thus eliminating the use of a large and expensive vacuum chamber. Weld penetration of 25 mm has been regularly obtained on stainless

steel at 9 kW beam power, and 24 cms/minute welding speed, while maximum penetration of 40 mm. has been obtained at 13 kW, and welding speed of 21 cms/minute. Savings in weld time and in materials costs will result as no edge preparation or any expensive filler metal is required, and materials as thick as 40 mm can be welded in a single pass at high speeds of 20 cms/minute.

An electron gun for a high voltage (150 kV) EB welding machine was tested extensively. At power levels of 4 kW, weld penetrations of 20 mm have been obtained in stainless steel at welding speeds of 20 cms/minute. At welding speeds of 100 cms/minute, penetrations of 10 mm were obtained, Because of its higher accelerating voltage, this machine is capable of giving finer beam; hence it will be more useful in areas requiring precision, such as aerospace and electronics.

Spectroscopy

A quantitative spectrochemical method for estimation of trace elements in lime stones was developed. This method was used to analyse various types of natural carbonates of geologically diverse ages collected from various parts of the country, and from different sea coasts. The Spectroscopy Division of BARC took part in the IAEA inter-comparison project for analysis of environmental samples. Results obtained on lake sediment samples received from the IAEA have been sent to that agency for comparison.

A spectrographic method, useful for analysing La, Y, Pr, Nd, Sm, Eu, Gd, Tb, Dy & Ho in percentage ranges in mixtures of rare earths, was developed. A method is being developed for the analysis of silicon for 14 trace impurities employing a d.c. arc run in nitrogen atmosphere. A project has been initiated to apply the thermoluminescence technique to the study of growth of coastal beaches and dunes.

Chemistry

Significant progress was made in research efforts in the areas of: (i) radiation and photochemical behaviour of materials (ii) thermo-chemical and phase transition phenomena of materials at high temperatures, and (iii) preparation and characterisation of volatile uranium compounds.

A new method was developed to obtain micro-crystalline photoactive chlorophyll, an important step in possible utilisation of solar energy via the photovoltaic route, as well as for understanding basic mechanisms.

Five different volatile uranium containing compounds were synthesized and characterised; the chemical intermediates required for the preparation of a few more such compounds were synthesized.

Developmental efforts were centred on: (i) technology for recovering gallium from Bayer liquor, produced in the aluminium industry (ii) screening and modifying lubricants and oils to obtain radiation-resistant products (iii) radiolytic oxidation of hydrocarbons and (iv) single crystal growth of intermetallics.

Laser-grade purity Coumarin 120, a very expensive dye used as dye laser, was synthesised in substantial quantity. After successfully completing scale-up studies on electrowinning of gallium from Bayer liquor, work was initiated at the plant site of HINDALCO where considerable quantities of the liquor have been electrolysed. Preliminary design studies of a pilot-scale gallium recovery plant were initiated.

Radiation polymerisation studies on cheap and fast growing local wood were continued, and sufficient improvement in the quality of the wood achieved to make its use in local industry, like woodcarving, commercially feasible. Several metallo-polymer compounds made in the laboratory have been found to possess very high dielectric constants. These compounds are being studied further to assess their potential use in microwave technology.

Analytical Chemistry

Geochemical studies of Ingaldhal metavolcanics showed striking similarities with rocks from different continents (India, Rhodesia, the USA) as regards rare earth element patterns, suggesting their origin to a common melting episode.

A number of minor and trace elements in a variety of ancient potshreds in the Ganga-Yamuna Doab were determined. A statistical treatment of the results enabled classification of these shreds into groups of common origin.

A number of collaborative research programmes with outside agencies were also undertaken. *e.g.* (a) Instrumental neutron activation analysis of a large number of head hair samples for twenty trace elements as part of IAEA-RCA project on environmental trace element pollutants (b) Sequential neutron activation analysis of two regolith samples collected by Luna-24 for twenty-five major, minor and trace elements as part of the Indian National Science Academy's (INSA) studies of lunar samples (c) Development of procedures for gas chromatographic estimation of traces of $CHCl_3$ and CCl_4, in water, under an IAEA Research Project.

Radiochemistry

The applied research and development programme in radiochemistry centered around the nuclear fuel cycle. Work was mainly on the preparation and quality-control of fuel materials, process chemistry, post-irradiation studies of fuel elements, and nuclear material accounting.

For the preparation of the fuel materials, UO_2-ThO_2 microspheres containing 5-15 per cent ThO_2 were prepared on a laboratory scale. A method for determining nitrogen in mixed oxides and nitrides with a precision of 5 per cent was standardised. An emission spectrographic method was developed for the determination of hafnium, niobium, tantalum and tungsten in plutonium oxide. Electrothermal atomic absorption spectrometric methods for direct determination of nickel, chromium, copper, manganese, and cobalt in U_3O_8 powder, and potassium and copper in uranium solution were developed. Using X-ray fluorescence technique, a method was standardised for determining uranium/plutonium in mixed oxides.

Several tens of milligrams of ^{238}Pu were prepared by irradiating ^{237}Np in CIRUS reactor.

The Radiochemistry Division participated in the inter-laboratory comparison experiment, "AS-76" on alpha spectrometry of plutonium samples, organised by Kernforschungszentrum, Karlsruhe, FRG, wherein 23 international laboratories took part. The values reported by the Division were among the best five.

Biology & Agriculture

Some of the steps in photo-synthesis were studied by stopping the process of photo-synthesis by lowering the temperature and making measurements on the light energy given out by such samples as the temperature was gradually raised. The glow thus obtained shows

six different peaks as the temperature is increased. These peaks can be divided into three groups, one of which does not appear to take part in the photosynthesis at all, while the other two appear to belong to two photo-systems characterised by the wavelength of the light they absorb. In most cases, the storage of absorbed energy is for very short periods, just a few seconds. Chemical and physical treatment of the leaves also show that some of the chemical constituents of the leaves are responsible for these light emissions.

When fertilizers are applied in the form of nitrate, they are converted by the plants into nitrites, ammonia, and finally, amino acids. The function of two of the enzymes involved in this conversion, namely, nitrate reductase and transaminase, were investigated.

The possibilities of conserving part of the carbon dioxide released during photo-respiration were examined. The enzyme oxygenase plays an important role in releasing CO_2 and the results suggest that by blocking its activity, it may be possible to regulate the loss of CO_2, which could be used for increasing productivity.

The absorption, transport and redistribution of essential plant nutrients were studied in beans using labelled iron, manganese, zinc and molybdenum. Iron was effectively translocated to all parts as long as it was available to the roots. Furthermore, the capacity of the bean roots for absorbing iron or manganese decreased with age. The presence of iron in the absorption medium enhanced the absorption of another micronutrient, molybdenum.

Studies on the contamination of soils and plants by plutonium-239, which is a constituent of global fallout and a pollutant released accidentally from nuclear installations, indicated that higher contents of clay minerals, especially of the 2:1 layer type (*e.g.* montmorillonite), and organic matter can reduce the plant uptake of this radionuclide. The plant uptake of chromium, an industrial pollutant, and radio-chromium, an activation product from nuclear reactors, studied through nutrient culture experiments, indicated a significant increase in the accumulation of this element in bean plants when the salt concentration of the nutrient medium was reduced,. Chromium was found to be mainly associated with ionic forms and lipids in the edible tissues of bean plants.

Growth analysis of high-yielding groundnut mutants has indicated that the rate of dry matter accumulation and plant dry weights at maturity are higher than in the parent variety. Foliar spraying of gibberellin (GA3) during flowering increased biological yield and pod yield. Application of ALAR-85 (Anti-gibberellin) at the same stages had the reverse effect, suggesting that biomass production itself could be limiting in realising yield.

In *mung* bean, spraying of kinetin, which retards senescence, and urea during the flowering period significantly increased grain yield by enhancing the number of pods. Both treatments delayed yellowing of leaves. These results indicate that the availability of nitrogen may be limiting yield in this crop. Response to fertilizer nitrogen was studied for 45 *mung* genotypes.

Trombay groundnut cultivars TG-1, TG-3 and TG-17 performed well at the cultivators fields in Gujarat, Maharashtra, Karnataka, Andhra Pradesh and Madhya Pradesh. Over 2,500 tonnes of seed of these cultivars were produced in the kharif season under the improved

seed multiplication programme of the Vanaspati Manufacturers Association of India.

Bold seeded and early-maturing Trombay *tur* cultures were among the top five in the north-west plains zone in the co-ordinated trials. These cultures (TT-4, TT-5 and TT-6) also performed well at the cultivators' fields in Maharashtra. On the basis of good performance for the past 3 years, TT-6 is now included for trials in Gujarat.

The rice culture TR-17 significantly out-yielded the check cultivars at the Rice Research Station, Vadgaon, Maharashtra State, for three years. It is now being evaluated. TR cultures have been found to perform better under saline conditions and are being tested under saline irrigation, and on alkali soils.

Several promising selections combining high yield with increased grain protein content from the induced high protein in wheat mutant TW-1 were made. Genes responsible for high grain protein character from cultivars Atlas, Naphal and Maratta were introduced by hybridisation in popular cultivar, Kalyan Sona.

Statistically significant increase in fibre yield was obtained in all the five Trombay jute cultures at Bahraich, as in the previous years. These cultures have been promoted to the field evaluation trials to be conducted at fields at ten locations in Bahraich. A photo-insensitive mutant was isolated in *capsularis* jute. This mutant showed longer vegetative period and increased plant height.

A true-breeding thick cane mutant TS-1, induced by radiations, was found to be superior to its parent cultivar CO419 in respect of size, weight and pol percentage. In collaboration with the Deccan Sugar Institute, Pune, multi-location tests are now being carried out at 4 different agro-climatic zones in Maharashtra.

The deficiency in iron in the upland rice nurseries was corrected by seed soaking or adding iron to the soil. Addition of K_2O to rice nurseries corrected the iron deficiency and promoted its vigorous growth.

Among some important findings in this area are the following: indiscriminate use of pesticides may lead to a build-up of residues in the soils, and affect the crops. Sevin added to red sandy loam soil 40 times more than field concentration reduced the growth of plants, but in black clay loam soil, it had no influence. Defoltan, a seed dresser fungicide, was not phyto-toxic to plants grown in both the soils,. Persistence of DDT can be effectively reduced by flooding, and by organic matter amendment. This method of biodegradation was also found highly successful with the insecticide Hexachloro-cyclo-hexane.

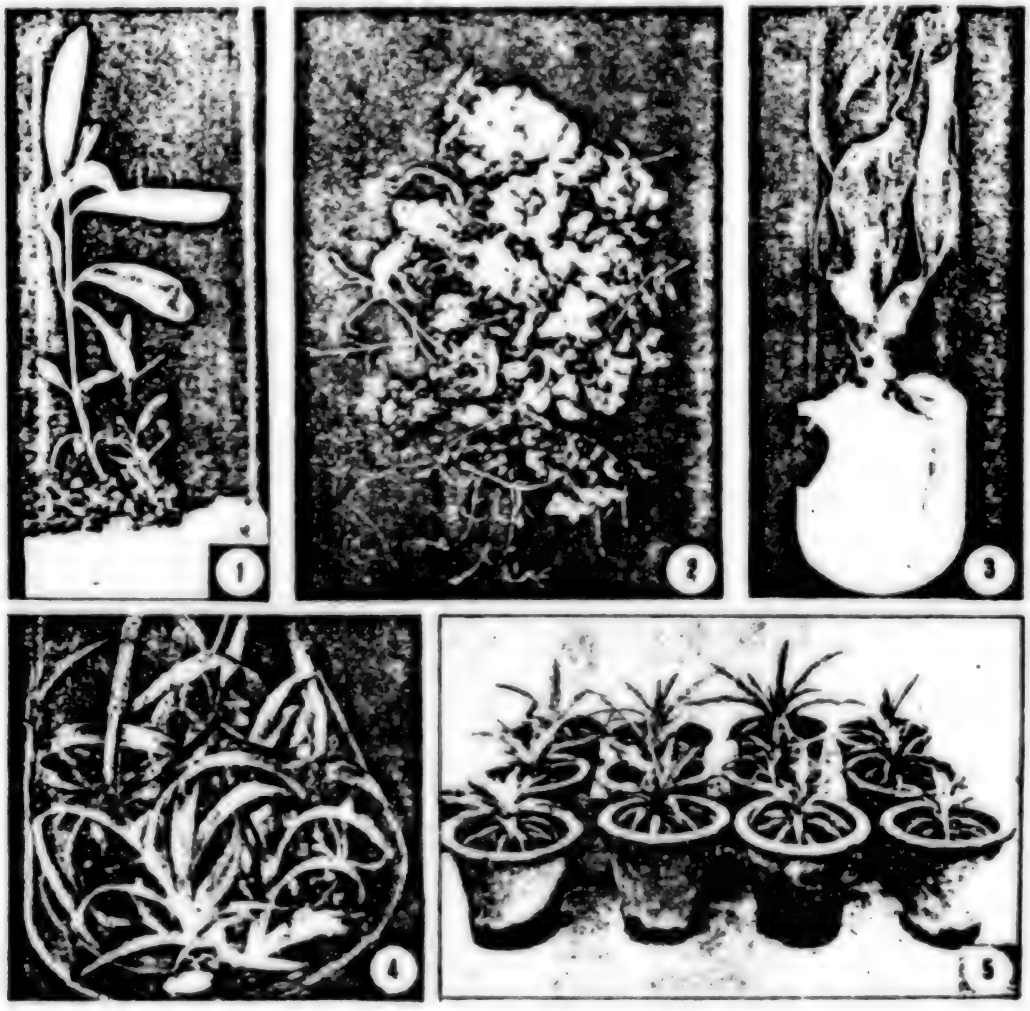
Bio-Organic Research: In bio-organic research, work on the propagation of sandalwood plants through tissue culture was actively pursued. In addition to the regeneration of shoot buds, hypocotyl segments also proliferated into a callus tissue which differentiated a large number of embryos. Such embryos developed into plantlets with roots. Production of a large number of plantlets through shoot buds and embryos would help in the vegetative propagation of the sandalwood plant.

Successful plant regeneration was obtained in organ cultures of an oil-yielding plant like mustard. Efforts are on to obtain plants with low erucic acid content in its seeds. Parameters for

vegetative multiplication of hybrid varieties of red pepper and egg plant through tissue cultures were determined. The plants obtained *in vitro* were established in soil where they flowered and bore fruit and seed.

Radiation Preservation of Food: In the area of Radiation Preservation of Foods, a radiation-heat combination process was developed for preparing fish protein concentrate from Bombay duck. The product displays a higher protein efficiency ratio. Conditions for radiation-sterilisation of fish at liquid nitrogen temperature were worked out. Fish fillets so processed retained texture and other organoleptic attributes. Transportation studies on irradiated and unirradiated fresh water fish (*Calta catla*), and mackerel (*Rastrelliger kanagurta*) were carried out, which again proved the efficacy of

Test tube plants nurtured at the Bhabha Atomic Research Centre. 1. A fully grown sandalwood plant, and a large number of shootbuds induced on an excised hypocotyl segment of the plant. 2. A number of sandalwood plants arising from mass of tissue. 3. A complete pineapple plant grown in a test tube. 4. Multiple pineapple plants developed from a bud in a flask culture. 5. Test tube plants of pineapple successfully transfered to soil.



the radiation process in prolonging the shelf-life of fish. A combination of dry heat and low-dose gamma irradiation treatment extends the shelf-life of semi-dried bananas at ambient temperature.

A laboratory-scale process for defatting of groundnuts was developed.

Large-scale studies on freeze-drying of mangoes, and on packaging for commercial distribution were carried out.

As in the past, several studies based on conventional methods of food processing, and on analytical techniques for the evaluation of nutritional qualities and safety of processed foods, were conducted. A method developed by BARC for determining extractives from plastic packaging materials has been adopted by the Indian Standards Institution as a standard test.

Micro-nucleus tests with mice have demonstrated that long-term feeding of irradiated mackerel do not result in any deleterious effects on chromatin.

Biochemistry

A number of studies were devoted to elucidating the diverse roles played by vitamins in the regulation of cellular and organ functions.

Regulatory aspects of mammalian metabolism were studied in animals subjected to stress conditions and development period.

Several research programmes on biochemical aspects of toxicity and mutagenicity of environmental chemicals are underway.

The mechanisms of radiation injury and repair formed an important part of the research programmes. Both nuclei and chloroplasts of *Euglena* cells were found to be capable of repair of their radiation-damaged DNAs. The efficiency of DNA repair in nuclei of light-grown cells (containing chloroplasts) was far greater than in nuclei derived from dark-grown cells (devoid of chloroplasts). The susceptibilities of the components of Yoshida ascites tumor chromatin, *viz*. DNA, histones, acidic proteins, were found to be greater when UV or gamma-irradiated individually, than when chromatin is irradiated. This suggests that the conformation of chromatin exerts a kind of protective effect against irradiation.

Radioisotopes

The isotope programme was expanded and diversified. The developments during the year under this head in the areas of medicine, industry and agriculture and R & D are given here.

Radiopharmaceuticals : Over 32,000 consignments of 50 radiopharmaceuticals, including injections, orals, kits for *in vivo* diagnostic investigations and radio immunoassay kits were processed and supplied to hospitals and medical research institutions. It is estimated that more than 200,000 patient investigations have been carried out in the country using the radiopharmaceuticals and services offered by BARC. Important radiopharmaceuticals such as radioactive vitamin B-12 were exported to many countries, including advanced countries such as Australia, Denmark and France.

Radioimmunoassay. An important item developed during the year is the radioimmunoassary kit for angiotensin-I. Angiotensin-I measurement by radioimmunoassay is a very reliable index of plasma renin activity and is very useful for distinguishing hypertension due to renal causes from other forms of hypertension, and for its treatment.

Two radioimmunoassay kits for T_3, T_4, developed during the last two years were introduced into the market for regular use. It is estimated that more than 15,000 patients have benefited using the RIA for these hormones. Radioimmunoassay services were extended to various user institutions. More than one thousand samples from hospital and veterinary institutes were analysed for T_3, T_4 insulin and HPL.

Generator-produced Radiopharmaceuticals. A significant development in this area is the preparation of ^{99m}Tc-labelled hepatobiliany agents, namely, ^{99m}Tc-Diethyl IDA and ^{99m}Tc para butyl IDA. These two derivatives of immuno diacetic acid are very useful for diagnosis of liver diseases and disorders of the gall bladder.

Radiopharmaceutical Laboratory Project. Work was taken up on the new Radiopharmaceutical Laboratory Project at Vashi.

Radiation Sterilisation of Medical Products. The ISOMED plant at Trombay offers radiation sterilisation service to manufacturers of medical devices, hospitals and pharmaceutical industries. A total of 1,610 cubic metres of various medical products were sterilised during the year. A pre-sterilised kit for use in domiciliary maternity procedures in rural areas was developed, and 50,000 kits have been supplied to the Department of Health and Family Welfare. Research and development work for extending the scope of the radiation sterilisation technique to pharmaceutical substances was continued. The feasibility studies for radiation treatment of papain, gelatin and gelatin capsules, and radiation sterilisation of absorbable gelatin sponge were completed.

Processed Isotopes. During the year, 240 batches of different radioisotopes were processed with a total activity of 700 Cis. A major part of this lot was supplied for the preparation of radiopharmaceuticals, and include isotopes like ^{131}I, ^{32}P, ^{51}Cr, ^{99}Mo, etc. A total of 1,000 consignments of isotope products was supplied to different customers; 19 consignments of this number were exported to countries like Malaysia, Singapore, Sri Lanka and Indonesia.

Sealed Radiation Sources. Sealed radiation sources such as cobalt-60, and iridium-192 are used extensively in medicine and also in industry for radiographic purposes. During the year, there was an increase in the supply of sealed sources of cobalt-60 amounting to a total activity of 127,000 Cis, of which 31,000 Cis. were supplied as nine teletherapy sources.

Radiation Technology. A Panoramic Batch Irradiator (PANBIT) was successfully commissioned at a plywood firm at Baliapatam, Kerala, during the year. The unit at present houses 50,000 Cis of ^{60}Co. A similar unit is being installed at the Pasar Jumat Research Centre, Jakarta, Indonesia. All the necessary equipments were shipped to the site and various embedments in the civil construction were carried out. The radiation source of the unit (80,000Ci ^{60}Co) has already been shipped. A special shipping container was designed, developed and fabricated for the purpose to meet the stringent international safety standards. Meanwhile, work on design and fabrication of two more cobalt-60 units was taken up, each unit capable of housing upto 100,000Cis of ^{60}Co. These units are proposed to be installed at Shree Chitra Thirunal Medical Centre, Trivandrum, and the Nuclear Research Laboratory, Srinagar.

Radiation Process Development. Trial

runs of a high volume impregnation facility, set up for development of wood polymer composites and their market evaluation were carried out.

Design and engineering details of a Sewage Sludge Research Irradiator (SSRI) for hygienation of sewage sludge are being worked out. The irradiator will treat about 100 M^3 of sewage sludge per day with gamma radiation from cobalt-60 of an installed capacity of about 300,000 Cis.

Radiotracer Techniques. At the request of M/s. Hindustan Steel Ltd. and the Indian Oil Corporation, a radiotracer technique was successfully developed, field-tested and applied to detect minute leaks in the 140 km long Koyali-Viramgam oil pipeline. Using bromine-82 as the radiotracer and a specially designed detector-recorder system, it was possible to detect and pinpoint the location of very minute leaks in the buried pipeline. The use of radiotracer technique saved at least 6 months time in testing and commissioning of the Viramgam-Koyali pipeline, which is a vital link in the expansion programme of the Koyali refinery. Besides, the inspection was carried out at less than one-tenth of the cost of the conventional techniques.

A radiotracer investigation was successfully carried out at the Lakya dam site at the Kudremukh Iron Ore Project to examine the nature of the geological fault noticed at the dam site during the excavation operations. As the Lakya dam will store iron ore waste, it was essential to know whether the fissure was connected to the river flow, thus polluting the river water. The radiotracer study showed that the fissure was connected to the two points at which seepage had occurred through an underground reservoir and that it was not connected to the river flow. Based on the results of the radiotracer investigations, the project authorities could take remedial measures without any loss of the project time.

The dynamic characteristics of a spray dryer unit and a fluidised bed dryer unit under development at a firm in Bombay, was studied using radiotracer techniques. The results of radiotracer investigations helped in finalising the design of the equipment.

A method for determining the inventory of mercury in electrolytic cells using the isotope dilution technique was developed. The technique was employed at a chemical factory in Bombay and was found tc provide a better estimate of the mercury inventory than the conventional methods.

Labelled Agrochemicals. Labelled agrochemicals such as superphosphates, nitrophosphates etc. are used widely in agricultural research. To cater to such needs, 15 kg of various agrochemicals labelled with isotopes such as ^{32}P, ^{35}S, ^{45}Ca were prepared and supplied to different agricultural institutions in the country. In addition, 4 kg of single and triple superphosphate (^{32}P) were exported to Bangla Desh, Sri Lanka, etc. On a special request from the Central Plantation Crops Research Institute, Kayamkulam, Kerala, ^{32}P- labelled ammonium dihydrogen phosphate, superphosphate and nitrophosphate (with 30 per cent water solubility) were supplied.

Hydrology and Tracer Investigations. The effectiveness of percolation tanks in providing water to the wells dug in the command area of the tanks is being investigated using radioisotope techniques, in collaboration with the Directorate of Irrigation Research and Development, Government of Maharashtra.

Studies are in progress at the Bangarwadi percolation tank in Osmanabad district.

The major developments relating to instruments for use in this area during the year are : (i) Liquid crystal display systems were prepared for use in digital watches, and rectangular flat tritium light sources, and sent to the National Physical Laboratory, Delhi, for evaluation. (ii) A remote-operated pencil shearing device was designed and fabricated. Using this equipment, about 80,000Cis of cobalt-60 was recovered from irradiated sub-assembly of the RAPP Cobalt adjustors (iii) A constant acceleration Mössbauer spectrometer was set up. Mössbauer sources using cobalt-57 on palladium, copper, iron and vanadium matrices were developed and supplied. Development work on the preparation of tin-119 sources is in progress. A facility is being set up for large scale preparation of americium-241 ceramic sources for use in smoke detectors. (iv) Seven gamma chamber units, having about 2,000 Ci each, were installed in various institutions in the country. About 60 radiography cameras were supplied to industry for non-destructive testing. (v) Special level detectors and static charge eliminators were fabricated and supplied to the industry to meet their requirements.

Applications in Research. A new technique has been developed for the removal of binder solution while preparing self-luminous tritium light sources. Using this technique, sources with improved light output and having very small diameters and intricate shapes have been prepared.

Tritium targets for use in electron capture detection instruments for studies in the evaluation of agrochemicals are in constant demand. During the year, a total of 78 targets and sources were supplied.

Among the different short-lived fission products produced as a result of fission of ^{99}Tc, the daughter of ^{99}Mo is a versatile tracer for diagnostic studies. A facility for large-scale separation of ^{99}Mo using the hydrochlorination-sublimation technique, developed earlier, was set up for testing the method at curie levels.

The flow sheet developed for the sequential separation of long-lived isotopes like caesium-137, strontium-90, using inorganic exchangers, was tested at 100 mCi levels. The products have been found to be satisfactory.

Radiation Medicine

During the year, more than 19,000 patients attended the Radiation Medicine Centre for various types of radionuclide investigations, assessment, examination, treatment and follow-up. The RMC acquired another scintillation camera with a data processing unit and a video-tape recorder which will be useful for dynamic function studies. The versatility of the new gamma camera and on-line computer system has been further enhanced by a locally fabricated E.C.G. gated device, which will permit more sophisticated cardiac studies for the detection of coronary insufficiency.

Research in Infectious and Tropical Diseases. The RMC has an active research programme for developing a radioimmunoassay for tuberculosis antigen. Such an assay would be very useful in the diagnosis of extrapulmonary tuberculosis. The radiometric technique utilising ^{14}C-labelled glucose developed at the Centre, for detecting micro-organisms in biological samples, is being employed on a larger scale for

detecting bacterial contamination in urine and sputum. Work is in progress for detecting tubercular bacilli in sputum and cereberospinal fluid, and for finding out the sensitivity of the organisms to anti-tubercular drugs. Studies on the behaviour and kinetics of ^{99m}Tc-labelled eosinophils in tropical eosinophilia are being pursued.

Pulmonary Ventilation Studies. In collaboration with the Health Physics Division, an inexpensive and simple aerosol nebuliser system has been developed and fabricated for producing radioactive aerosols for inhalation lung scans. The nebuliser is not only very cheap in comparison with the ultrasonic nebuliser (which has to be imported), but has been found to be better in performance. Inhalation lung scans have been performed with ^{99m}Tc-phytate aerosols and have provided useful information in patients with chronic obstructive lung disease. In order to elucidate the mechanism and kinetics of alveolar absorption, dynamic, pulmonary function studies are also being done with ^{99m}Tc absorbable aerosols.

Scintigraphy. About 4,500 patients underwent liver, brain, bone, thyroid, kidney, heart and lung imaging studies during the year.

In Vitro and Radioimmunoassay Studies. More than 3,500 patient samples were assayed for TSH, T-3, T-4 and HGH levels in the plasma by radiommunoassay. Radioimmunoassay for thyroglobulin was developed and standardised at the Centre. Such standardisation would be useful for patients of thyroid cancer.

A simple method to label the patient's red cells with ^{99m}Tc-pertechnetate *in vivo* was developed. ^{99m}Tc-labelled red cells would be useful in blood pool imaging studies and in dynamic radiocardioangiography studies.

Radiopharmaceuticals. Ready-to-use kits to make radiopharmaceuticals for various investigations are being made at the Centre. A kit for making ^{99m}Tc-EDTMP was developed and successfully tried for bone imaging studies in patients. ^{113m}In-phenolphthalein was developed as a new hepatobiliary agent.

Thyroid. In addition to carrying out a large number of *in vivo* and *in vitro* radioisotopic procedures, including radioiodine uptake, scans, radioimmunoassays for T-3, T-4 and TSH, 63 thyroid cancer patients, and 42 patients of hyperthyroidism were treated with radioactive iodine. Work is also in progress to elucidate the mechanism of action of anti-thyroid drugs like propilothiouracil (PTU) and methimazole (MMI).

Medicine

Mammalian Radiobiology: Reproductive efficiency, as reflected in terms of litter size and foetal loss, was assessed in mice exposed to sub-lethal doses of radiations. Pre-treatment with 5-Hydroxy tryptamine was found to afford significant protection.

Exposure to radiations of the thymic region at birth causes, in adulthood, thymic atrophy with prominence of fibrous tissue or accumulation of reticulo-epithelial cells. Concurrently, splenomegaly is observed, accompanied by lympho reticular proliferation. There is also an abnormal increase in the number of granulocytes. An interesting finding is the development of a condition resembling myasthemia gravis in humans.

Studies on the effect of gamma rays on different lymphoid cells involved in

immune response revealed that the helper cells participating in humoral response are more radiosensitive than the effector cells responsible for cell mediated immunity.

In vitro: Investigations on the effect of radiation on human haemoglobin showed that presence of chlorpromazine during irradiation causes enhanced radiation damage.

Metallurgy

The activities in metallurgy have been concerned with : (i) development of processes for the extraction and refining of rare metals and special materials for application in the nuclear engineering, electronics, aero-space, and chemical industries, (ii) basic studies on the physical and mechnical metallurgy of special metals and their alloys, (iii) the science and technology of corrosion and its prevention in industrial environments, (iv) development of nuclear ceramics and high temperature ceramic materials for advanced reactors and the MHD programme, and (v) development of special fabrication techniques involving powder metallurgy and electroforming.

Boron carbide was in regular production in specially designed graphite resistance furnaces, to meet the requirements of the reactor programmes. About 120 boral plates were fabricated for use in the R-5 reactor as neutron shield material. Another 150kg of B_4C powder were produced for control rod applications in the Tarapur Station. Crystal bar hafnium was prepared from calcium reduced metal, and is under evaluation for fabricating thin metal strips to be used as control rod material.

Graphite-coated zircaloy tubes developed for CANDU-type reactors have shown excellent performance when subjected to different destructive and non-destructive tests. Long lengths of Nb-Ti super-conducting wires sheathed in OFHC copper were prepared and evaluated at the Reactor Research Centre. The salt roasting process for the recovery of nickel from the Jaduguda sulphide concentrate was successfully examined on kilogram scale in a multiple hearth furnace. A much larger scale experiment has been planned.

Civil works are in progress for the Beryllium Pilot Plant, being set up for the Departments of Space and Electronics. The plant has an initial capacity of 10 tonnes of Cu-2% Be alloy, and 250 kg of vacuum hot-pressed beryllium, needed for space and electronics applications.

A programme for development of plate-type fuel is being pursued; the conditions for the preparation of thin sintered platelets of UO_2 have been optimised, and regular fabrication of the platelets has been taken up for assembling the prototype elements.

In the field of high temperature oxide ceramics for MHD channels, work is in progress on the fabrication of a large number of sintered alumina blocks of diverse shapes and sizes for lining the MHD test channel; they will be sent to the USSR for over-all testing during 1979. Development of high alumina components for electronic applications by BEL has reached an advanced stage. The bodies developed were evaluated by BEL and found to meet its specifications.

Radiometallurgy

In the Hot Cell facility of the Radiometallurgy Division, post-irradiation examinations were carried out on the fuel elements from reactors, including

one experimental R-5 fuel bundle, and one defective fuel pin.

Fabrication of the first set of 68 FBTR dummy pins for hydraulic and endurance studies at RRC, Kalpakkam, was completed. Work is in progress on the fabrication of experimental fuel pins for irradiation in the pressurised Water Loop.

Extensive work was done on the development of carbide, nitride and carbo-nitride fuels for advanced liquid metal-cooled fast breeder reactors. Flowsheets of reproducible and optimum fabrication parameters were developed for preparation of powders and sintering of pellets. Preliminary compatibility studies of the helium and sodium bonded carbide and nitride fuels have shown excellent compatibility with Type 316 stainless steel.

A plutonium homogeneity scanner, using an external radiation source for the inspection of Al-Pu alloy plate-type fuel elements, was developed.

Ore Dressing

A flow-sheet was developed to upgrade the fluorite ore from Kahila, Rajasthan. Flotation with oleic acid and ethyl alcohol as collector frother, followed by three stage cleaning of the rougher float using sodium silicate and bleaching powder, gave a concentrate assaying 98 per cent fluorite, with a recovery of 90 per cent. Pilot plant runs were carried out to optimise the process parameters determined during the batch scale testing.

Investigations were conducted on graphite ore from Almora, U.P. The mineral is fine-grained and occurs mainly as a coating on other gauge minerals. Calcining the ground ore at 750°C and quenching it before flotation was found to improve the grade and recovery.

Special Materials

Studies were continued on the extraction and refining of thorium and zirconium, preparation of stable isotopes, scintillation chemicals, labelled compounds and sulphur hexafluoride, and also on the recovery of helium.

Pilot plant operation for the recovery of thorium concentrate and its purification by direct solvent extraction processes was continued. The design of a pilot plant scale distillation set-up has been completed and work on the purification of helium, and analysis of helium content in various gas samples has been carried out.

Studies on the separation of stable isotopes of boron, nitrogen, argon, etc. were continued. Production of nitric acid, containing upto about 40 per cent ^{15}N, was carried out in the Nitrox Pilot Plant. From this acid, compounds such as urea and ammonium sulphate were prepared and supplied to various institutions. A thermal diffusion column was set up for studies on the separation of helium and neon.

Preparation of deuterium labelled compounds and scintillation chemicals, PPO (2:5 Diphenyloxazole) and POPOP (1:4 Di2,5 phenyl-oxzaolyl-benzene) was continued to meet the requirements of the various units of the DAE and other research organisations in the country.

Production of fluorine gas by electrolysis of potassium bifluoride using carbon anodes was continued. Starting with fluorine gas, kilogram quantities of sulphur hexafluoride were produced and supplied to various research groups. The design of a pilot plant for increasing production of sulphur hexafluoride was completed.

Production of nuclear grade uranium

metal was continued for making fuel elements for CIRUS. The project report for the expansion of the plant to about three times its present capacity was approved. Development work on magnesio-thermic reduction of uranium, solvent extraction using mixer-settlers, and processing of the effluents for disposal and recovery of byproducts is in progress.

Work was carried out on the recovery of uranium from its ores, development of a process for semi-conductor grade silicon and silcon compounds, and separation of rare earths.

Besides running a pilot plant for the preparation of trichlorosilane and the ultimate production of pure silicon, work on the preparation and testing of octyl silicate as diffusion pump liquid, was continued. This material appears to be suitable as a substitute for the imported diffusion liquids.

Reactor Control

Major items of work in this area during the year include the following: (i) Physics design of a plutonium-fuelled pressurised light water nuclear reactor with the fuel rods distributed in boxes, and with cruciform control rods and chemical shim. This was completed, and all aspects of core design, control and burn-up behaviour were investigated. (ii) *Computer-Controlled Fuel Handling System for NAPP:* For the control of the fuel handling system for NAPP, a distributed computer system, using one TDC-312 computer and two micro-computers, is being developed. The design for an in-house Intel 8085 based micro-computer (MIDGET), an inter-processor communicator unit, the digital and analogue sub-systems, and the operator's console for the system were completed, and their cards are under fabrication. (iii) *Computer-Based Gamma Scanner for RRC (COBAGS):* Printed cards for data acquisition, data display and operator's console were fabricated, tested and are now being assembled. The development of the software for this system and its documentation have been completed. The entire hardware for this project is expected to be completed by next year, after which the system will be ready for operation. (iv) *Passive Gamma Scanning System for FBTR Fuel Pins:* A system is being developed to estimate the inventory of the fissile material in the FBTR fuel pins prior to irradiation in the reactor. (v) Sodium pump speed control system for FBTR. (vi) *Fission Couple:* The development of fission couple, a miniature fast response neutron detector, which can be used to monitor short and intense neutron pulses, was completed. A new version of fission couple, which can monitor neutron flux in the reactor core and which can withstand very long exposures at high temperature and pressure, is under development.

Reactor Chemistry

The expertise developed in the field of power reactor water chemistry was made available to other DAE units as well as to the thermal power stations of the various State Electricity Boards, and to the Central Electricity Authority. Based on a detailed study on the process cooling water chemistry at the Heavy Water Project, Tuticorin, chemical additives were recommended which are now being used by the plant. Technical advice was provided on (i) improvement of water chemistry and minimising corrosion of copper tubes at VEC, (ii) chlorination of sea water coolant at the Tuticorin thermal power project and (iii) proposed use of LiOH addition to boiler water at Ennore thermal power station.

Under the Indo-German collaboration

agreement, there was an exchange of scientists for work in the field of water chemistry.

Reactor Engineering

Activities during the year were concerned with research and development for the power and experimental reactors in operation, those under construction, and those being designed. The following are some of the activities undertaken :

(i) A new liquid poison shut-off rod system was designed for the Narora Atomic Power Station.

(ii) For MAPP-II, nine calandria support rod assemblies were completed and delivered at the project site. The acceptance testing of the first fuelling machine for MAPP, and thermal shock-testing of fuelling machine and fitting was completed.

(iii) *Thermal Hydraulics.* The 10 MW freon loop was commissioned. Work on the procurement and fabrication of equipment for the 1.2/3 MW Boiling Water Loop is on. Thermal hydraulics analysis required for TAPS fuel management was carried out on a continuous basis.

(iv) *Nuclear Economics and Fuel Cycle Studies.* An investigation was carried out to ascertain the feasibility of running the heavy water power reactors on a self-sustaining thorium fuel cycle, starting with natural uranium fuel. The physics aspects of a heavy water reactor with fuel and coolant in the form of a slurry were examined to see whether it can be a self-sustaining thorium fuelled reactor.

(v) Work under a contract with the International Atomic Energy Agency was continued for the evaluation of nuclear data related to thorium utilisation. Work on reactor codes was done as a complement to reactor experiments and for testing a multigroup data set.

R-5 Project. Work on the wholly indigenous 100 MW thermal research reactor project at Trombay registered good progress.

The reactor building and service building civil works are nearing completion. Civil works for reactor annexe, attached laboratory, guide tube laboratory, stack and filter house are in progress.

Manufacture of reactor vessel, coolant channel assemblies, end-shield, annular shield, deck plates, fuelling machine, heavy water and process water heat exchangers, process water and sea water pumps, S. S. tanks, main air compressors, air locks, etc. is in progress at the vendor's works.

Stainless steel lining for sequency dump tank and reactor hall sump has been completed and reactor vault lining work has been taken up. Irradiation of fuel assemblies for the reactor is continuing in the CIRUS reactor.

Fuel Reprocessing Plants. In the Tarapur Fuel Reprocessing Plant, the first campaign of trial run with spent fuel was successfully completed, and preparations are now being made for starting the next campaign. The installation of the ECIL computer for data processing was completed and its testing and commissioning are in progress.

For the expansion of the plutonium plant at Trombay, fabrication of process equipment is in progress.

A detailed design of the Kalpakkam Fuel Reprocessing Plant is in hand.

Electronics

Nine criticality monitoring systems, fabricated for the Radiometallurgy Division, were upgraded for early detection of criticality accidents and initiating emergency warning procedures. Two ruggedised scintillation probes for high altitude applications, including a dynamic simulator, were supplied to ADE, Bangalore. A specific gravity gauge for monitoring the density of caustic soda flur was developed for an aluminium plant. An instrument to measure thickness of aluminium foil in a continuous rolling mill is being designed.

The instruments presently operating at APSARA, ZERLINA and CIRUS reactors are being replaced by third generation products. Control channels for PURNIMA reactor and Campbell Channel for R-5 reactor were developed. Neutron detectors for R-5 operation are under fabrication.

A report on the status of nuclear medicine instruments in the country was submitted to the IAEA. An improved model of an isotope calibrator unit was developed. An experimental system to investigate ulnar leprous neuropathy, was designed, fabricated and tested for use in the Acworth Leprosy Hospital, Bombay.

An experimental ultrasonic B scan system is under development to screen internal organs for clinical diagnosis.

An automatic gamma counting system which can handle 240 samples is being developed to conduct radioimmunoassay studies.

Defence grade wet tantalum capacitors (600 pieces), and energy storage capacitors (24 pieces) were fabricated and supplied to various divisions of the Centre.

Reliability Evaluation

The Reliability Evaluation Laboratory offers services such as environmental/electrical testing, electronic instrument calibration, special studies and training to industries and institutions located in the western region of the country. During the year, about 170 requests were received for environmental/electrical testing of a variety of electronic and allied components. These items were evaluated according to various IS, IEC and JSS specifications. About 45 requests were received for calibration of instruments such as precision resistance and universal bridges, standard resistances, digital panel meters, thermocouple potentiometers, DC and AC voltmeters, ammeters and watt-meters, etc.

Seismology

The Seismic Array at Gauribidanur was in continuous operation and all the major underground nuclear explosions were detected. Three long-period seismometers, one at each of the extreme points, and the other at cross-over point of the array, have enhanced the seismic source discrimination capability of the array. The microbarograph system is also in continuous operation.

An agreement was signed with the UNDP to supply 20 units of timing systems developed in the Seismology Section at BARC. These units will be be deployed in the seismic stations operated in South East Asia by the Philippines Atmospheric Geophysical Astronomical Service Agency (PAGASA)

A collaborative seismic project undertaken jointly with Bharat Gold Mines Limited, Kolar, made good progress. A network of 7 surface sensors, together with the telemetry and recording system, was established. Rock-burst signals are now being continuously recorded

on the analog tape with accurate time mark.

Instrumentation

The following are some of the items of work pursued, and systems developed by various units of the BARC during the year:

(i) A 2m diameter thermovacuum chamber for the ISRO Satellite Centre, Bangalore, designed by the Technical Physics Division, and fabricated and installed by Messrs. IBP, Bombay, was put into operation. The total cost of the system is Rs. 25 lakhs. The design of a much larger space simulation chamber, to handle subsystems for the proposed APPLE Project of ISRO, has now been taken up. It would be a 4 m diameter chamber, to operate in the range of 77-400°K, at a vacuum better than 10^{-6} torr. The cost of the system is Rs. 80 lakhs. Its fabrication and installation work will be handled by M/s. IBP.

(ii) Work on field-ion and field-emission microscope (FIM) was continued. Operation of the FIM at liquid helium temperature was carried out for the first time in the country. Desorption studies under ultra-high vacuum conditions were further pursued. Evaluation of octyl-based fluid for diffusion pumps was carried out, It was found that the oil gives excellent results for vacuum applications with high thermal stability. It has also a much better critical back-up pressure characteristics. A field emission X-ray tube is also being designed.

(iii) A programme on radiation detectors and crystal growth has been undertaken for the production of germanium single crystals of large diameters, KDP crystals as laser modulators, thermal imaging devices, large-size alkalihalide optical crystals, CaF_2, LiF crystals, PbS infrared detectors, infrared filters, surface barrier radiation detectors, and for development of crystal growing equipment.

(iv) A 150 cm diameter high-vacuum aluminium coating plant, built for the Indian Institute of Astrophysics, was installed at Kavalur. The plant is capable of handling telescope mirrors upto 125 cm. diameter. This is perhaps the largest indigenously designed coating plant. Another coating plant for the 225 cm. telescope mirror, at the same observatory, is being designed. A special purpose high-vacuum coating plant for laser applications is now ready.

(v) A sophisticated 4096 channel pulse height analyser has been built around the ECIL's mini-computer TDC-312. This knowhow is likely to be transferred to ECIL for large-scale production of the system.

(vi) BARC is carrying out the design and fabrication work relating to the telescope and drive system for a 1.2 m. infrared telescope being built by PRL, Ahmedabad at Mount Abu, for the study of infrared stars.

(vii) After extensive tests in the laboratory for traction and regeneration, a WAG-1 Control System unit was approved by representatives of RDSO, Lucknow, and S. E. Railway, Tata Nagar. The drive system was installed in WAG-1 Loco No. 20700 and recabling of various parts was completed. The system is presently undergoing operational tests.

(viii) The technology for laboratory-scale production of space quality silicon solar cells was developed. The sizes of the cells are 2×2 cm^2, and 1×2 cm^2. Several hundreds of such cells were fabricated and tested at the ISRO Satellite Centre. About 200 cells have been supplied. A test panel of 106,

2 x 2 cm^2 cells was made and tested for SLV-3 rocket.

(ix) A real time TDC-316 computer-based arrhythmia monitoring system to monitor continuously four patients of an intensive care cardiac ward is being developed for the BARC Hospital. The development of hardware to record ECG data on a casette tape and reproduce them faithfully for off-line analysis was completed. Preparation of the ECG analysis software and the coding of ECG data are in progress.

(x) A computerised X-ray tomography scanner is being developed. This system uses a computer to reconstruct detailed pictures of sections of the human body from a number of X-ray transmission readings taken around the body. Such computer reconstructed pictures have revolutionised the science of diagnosis.

(xi) A 2 MV terminal tandem accelerator was put into operation. A beam of 0.15/μA, of about 2 MeV protons, has been obtained with a terminal voltage of 1 MeV and preliminary experiments to identify the beam have been carried out. The accelerator is undergoing further testing and necessary changes to routinise the operation. The 5.5 MeV Van de Graaff accelerator, which is in its 17th year of operation, was overhauled; it has been working at better than 80 per cent efficiency since October 1978. A new ion source is under development for installation into the high voltage terminal of the accelerator, to provide heavier ion beams to extend the scope of present research programmes.

(xii) The DUMAS mass separator at Trombay started functioning; one limb was made operational and the machine performance was checked over the mass range upto the element lead (*i.e.* M = 206). The mass spectra taken for Ar, Kr, Xe and Pb indicate an average mass resolving power of about 450-500 over the entire mass region. Efforts are underway for the separation of uranium isotopes in minute quantities using the mass separator.

(xiii) The first indigenous, fully automatic computer-controlled single-crystal X-ray diffractometer was commissioned. The complete hardware and the electronics for this system, based on the ECIL computer TDC-312, were designed and fabricated in Trombay.

(xiv) A new unit of aerosol generation/inhalation system for aerosol scintiscanning of lungs was fabricated and supplied to the Iraq Atomic Energy Commission. A shadow shield scanning bed-type of whole-body counter of greatly improved design was fabricated and supplied to the Philippines for clinical radioisotope studies, against an order placed by the IAEA.

(xv) A gas chromatograph using a thermal conductivity detector to monitor hydrogen in air, with a sensitivity of 0.1 per cent, was designed and fabricated. The apparatus can also be used to estimate helium in geothermal gas samples, and hydrogen in submarine battery compartments.

Laser

The power in the neodymium glass laser chain was brought to 5 x 10^9 watts. An important feature of this laser is the electronic control system which controls the storing of 75 kilojoules of energy in 12 capacitor banks, discharging them with appropriate delays through the laser flash lamps.

A Quiescent Plasma Machine ("Q" Machine) was built with entirely indigenous materials, to produce "Quiet"

plasmas. Lithium plasmas with a density of 10^{11} ions per cubic centimeter were obtained at 2000°C.

Considerable progress was made in the development of the high power TEA CO_2 laser. One of the major problems in the efficient extraction of energy from a carbon-dioxide laser chain is that it operates on a single line. Use of a hot CO_2 gas as a suitable absorber for producing multiline oscillation in a TEA CO_2 oscillator, has been successfully demonstrated.

A 16-channel digital optical data link was developed which will be useful for monitoring data at short range from inaccessible installations such as the high tension point in a Van de Graaff generator.

Computer R & D

(i) *Data Acquisition Systems.* The knowhow for a 4096 channel data acquisition system, having 100 MHz A-D converter, was transferred to ECIL. Four units are being manufactured by ECIL based on this knowhow. Work was completed on a 1024 channel data acquisition system employing 100 MHz A-D converter. Development work was also undertaken on a portable dual A-D converter duel memory data acquisition system required for aerial prospecting for uranium.

(ii) *Solid State Instrumentation.* Work was completed on a microprocessor-based Mössbauer spectrometer system useful for solid state studies. This unit has a built-in microprocessor and DMA channel and will provide the user a compact and reliable system. The necessary application software needed for Mössbauer spectrometry has been developed. The design of an advanced Mössbauer spectrometer was completed and two units are being delivered, one to TIFR and another to the Chemistry Division.

(iii) *Computer Hardware.* A simple digital recording system on audio cassette at 110 bands per second rate has been developed. This system will be an inexpensive storage media for utility programmes on micro-computers.

(iv) *Digital Communications.* A microprocessor-based private automatic telephone exchange (PAX) was developed. The system can be engineered for incorporating the hardware upto 25 telephone connections, with two simultaneous connections being permitted. A microprocessor M 6800 maintains and updates the various status lists and processes dialing information by software. An auto-dialing facility having a small memory to store the desired number is also being incorporated. It will automatically dial as many numbers, as many times as required, without the need to re-enter the telephone numbers. A single microprocessor can easily support over 100 telephone lines.

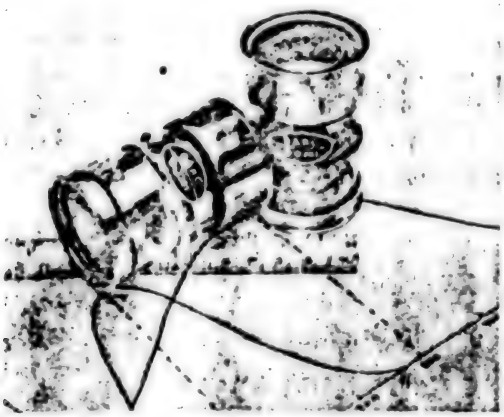
(v) *Dual Microprocessor System.* A dual microprocessor system built around the SC/MP microprocessor, and one MM 57109 (calculator chip) have been developed. The system, when integrated, provides a master-slave manipulation and acts as a data acquisition system.

(vi) *Data Logging Systems for Power Projects.* A disturbance recorder for RAPP is nearing completion, The system is based around the 8080 microprocessor and can record and print data from 20 different channels for a period of 5 minutes before and 5 minutes after the tripping event.

Opto-Electronics

Work on the development of image

intensifier tubes, as well as systems for night vision applications, was continued. A high voltage power supply unit with an automatic brightness control feature, required for the image intensifier assembly, was developed.



Infra-red converter tube used for night viewing, developed by the Opto-Electronics Section of the Bhabha Atomic Research Centre.

Two levels of specifications for the use of image converter tubes for various applications are being evolved. A new unit is being set up at Pune by Bharat Electronics Ltd. where the image converter tubes will be produced on a commercial scale. It is also proposed to transfer the technical knowhow for the monocular and binocular night vision systems operating in the active mode, developed earlier, to a suitable agency.

Radiation Protection

The following studies were carried out on: (i) the mechanism of attachment of radon daughter products to aerosols, to enable realistic evaluation of the inhalation risk to uranium miners, (ii) inhalation risks due to natural radioactivity in tobacco amongst cigarette smokers. This study was carried out using a helium-neon laser. (iii) the variations in the concentrations of total hydrocarbons in the ambient atmosphere. These gaseous hydrocarbons play an important role in the photochemical reactions taking place in the polluted environment. (iv) Analysis of Monsoon 77 data collected over the Arabian Sea, the Bay of Bengal and the Indian Ocean during 1977 has provided a better understanding of the atmospheric circulation pattern during pre-monsoon and monsoon periods and correlates well with the meteorological data collected during the same expeditions. The results have been utilised for studying monsoon dynamics more extensively during Monsoon 79 project. (v) Radiobiological investigations with yeast cells were carried out to obtain parameters of interest in radiotherapy and environmental pollution.

A pocket-type thermoluminescent personnel monitor was developed using glass encapsulated $CaSO_4$: Dy phosphor.

The programme of introducing TLD badges for personnel monitoring of radiation exposure was continued. $CaSO_4$: Dy phosphor embedded teflon discs were produced in large numbers. In order to meet the very large requirement, methods were developed to obtain $CaSO_4$: Dy teflon discs from tapes.

The Radiological Standards Laboratory and Radiation Standards Section maintains national standards for measuring beam outputs and activity of radionuclides. Gamma exposure primary standard inter-comparison between this laboratory and the National Bureau of Standards, USA, showed an agreement of 0.3 per cent, between them. Primary standards of ^{134}Cs, ^{137}Cs, ^{152}Eu and ^{54}Mn were prepared for comparison with other national standards laboratories.

A detailed study of short-lived fallout from Chinese nuclear explosion was

carried out in March 1978 to assess fallout levels at countrywide monitoring stations.

The countrywide personnel monitoring service for estimating radiation exposure covered about 45,000 radiation workers from nearly 2,400 institutions. Countrywide radiological protection survey, including supervision of source loading operations of teletherapy units, were conducted in 150 institutions, consisting of 122 medical, 11 industrial and 17 research institutions.

Advice in respect of installation planning was given in 978 cases connected with X-ray teletherapy units, industrial radiography units and radioisotope laboratories. Thirty-five installations were approved for final construction. Advice on the use of radiation sources, equipment and associated safety aspects was given in 2,474 cases.

Health Physics

Health and safety requirements were provided for the proposed Beryllium Pilot Plant, Boron Carbide Facility and for the extension building of the Uranium Metal Plant. Special industrial hygiene surveys were conducted at the IRE plants at Manavalakurichi and Chavara and Tear Smoke Unit, Border Security Forces, Gwalior.

A non-destructive assay technique based on the analysis of X-rays and isotopic gammas was developed to estimate both uranium and plutonium in mixed fuels.

Work was continued on the following projects under research contracts awarded by the IAEA : behaviour of transuranic nuclides in coastal environment; critical pathway studies on selected radio-nuclides; radium in natural and processing areas, and its impact on human environment; and characterisation of aerosols.

Work on IAEA projects such as 'Physical and chemical aspects of thermal discharges into a lake water system' and 'Tritium' was completed. Studies on the behaviour of tritium in the environment, with specific reference to aquatic media, were continued. It has been established that leaf sampling techniques are good indicators of tritium release patterns and dilution rate factors in and around heavy water reactors. An analysis of micro-meteorological data at Kalpakkam revealed that the stability indices for coastal sites could be different from those applied for homogeneous inland sites.

Evaluating Biological Effects in Monazite Belt.

In continuation of the efforts to evaluate the biological effects of high background radiation on human population residing in the monazite belt, chromosome analysis was carried out on 179 samples.

Under a Chromosome Analyses Programme, blood samples of people in normal background radiation areas and high background radiation areas in the Southern monazite bearing coastal areas were analysed. Data on newborn and their mothers did not indicate any differences in the chromosome aberration frequency between samples from normal background areas, and those from high background radiation areas.

In the samples taken from the Indian Rare Earths works at Alwaye a higher aberration frequency was indicated than that observed in the high background radiation, Chavara and Manavalakurichi samples.

Waste Management

Under the Radioactive Waste Manage-

ment Programme, the following projects are being handled:

(i) *Waste Immobilisation Project (WIP.) Tarapur*, to process and immobilise the high radioactivity wastes generated from the Fuel Reprocessing Plant at Tarapur, into inert non-leachable solids. (ii) *Solid Storage Surveillance Facility*, Tarapur, for interim storage of cannisters containing vitrified high level radioactive waste products, for a period of 20-30 years. (iii) *Centralised Waste Management Facility*, Kalpakkam , for treating low-level liquid effluents and decontaminating protective wears. (iv) *Effluent Management System for MAPP*, Kalpakkam. (v) A *Solar Evaporation Facility*, at Rajasthan for treating low-level liquid wastes by solar energy. (vi) *Waste Management Plant*, Narora, to take care of the low and medium level wastes likely to be generated at the Narora Atomic Power Plant. (vii) Effluent Management Facility for R-5 Reactor, Trombay. (viii) *Solidification Project*, Trombay, to process high, intermediate and low level radioactive wastes generated in the expanded Plutonium Plant at Trombay. (ix) *Effluent Management Unit* for Nuclear Fuel Complex, Hyderabad. (x) *Effluent Treatment Plant* for Indian Rare Earths Ltd.

The Research and Development activities related to the Waste Management Programme included the following : (i) Development work on suitable glass melts for incorporating high level radioactive wastes from the Fuel Reprocessing Plant (ii) Studies connected with separation and fixation of actinides in the wastes from the FRP (iii) Work on Impregnated Resin Exchangers for selective removal of radioiodine from liquid radioactive wastes. An experimental set up to treat 100 litres of the waste per hour was installed at Tarapur. (iv) Study of the water hyacinth, a rapidly multiplying aquatic biomass for its absorption of tritium. (v) Studies relating to filtration characteristics of naturally occurring gums and synthetic poly-electrolytes. (vi) Solar evaporation studies and investigations relating to treatment of chemical effluents. (vii) Studies for developing suitable solid adsorbents for removing radioiodine from high temperature gas streams, and for its retention over a long period. This work has led to the development of special high temperature iodine cartridge filters for use in the radio-metallurgical laboratories attached to the Fast Breeder Test Reactor at Kalpakkam. (viii) Development of special filters for ultra-filtration of castor oil for use in the manufacture of energy storage capacitors. In addition, off-gas filters have been developed for the Tarapur Atomic Power Station, in place of the imported ones currently in use.

Energy Research

Studies in this area covered the following :

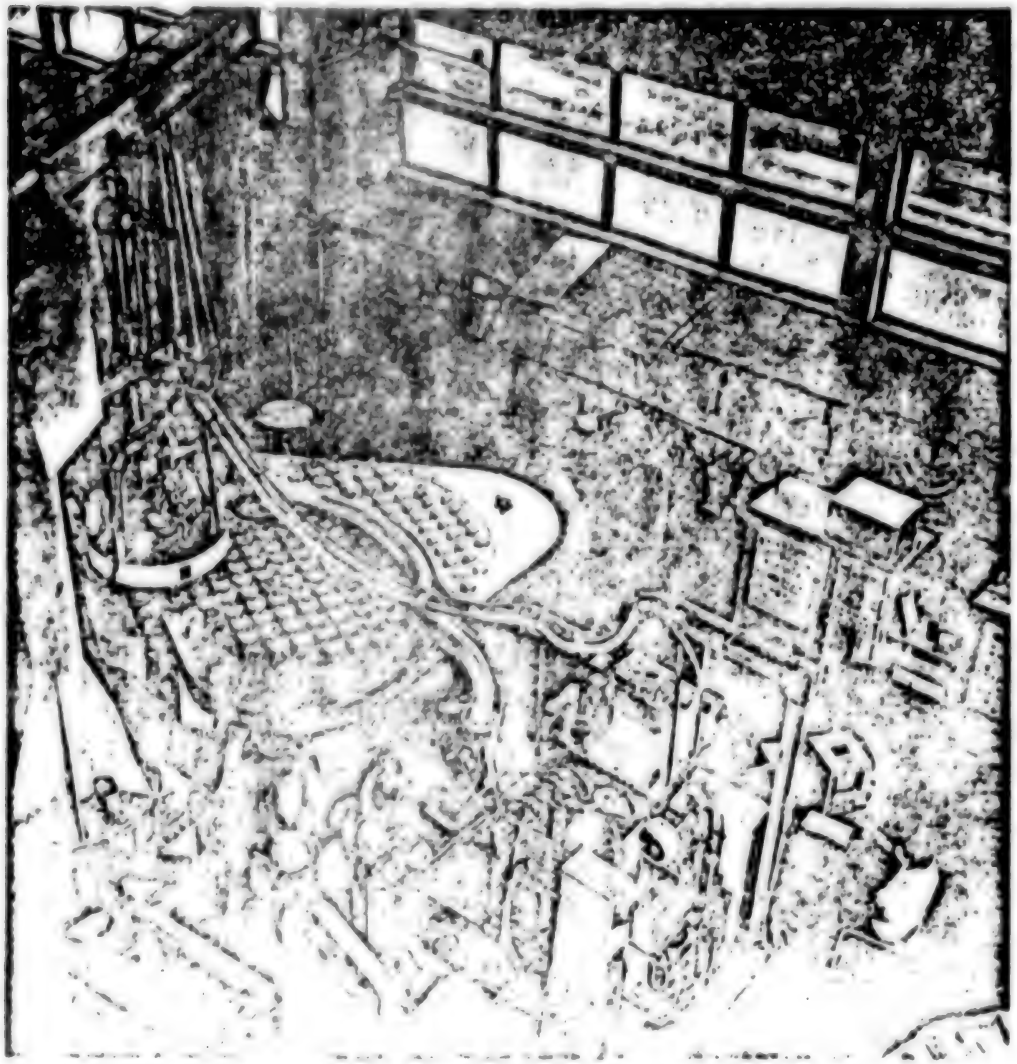
(i) *Desalination:* Two pilot plants—a Multi-Stage Flash Distillation Plant, and a Vertical Tube Evaporator Plant—are in operation at Trombay. The former has been operated for about 2000 hours, and has provided enough data for designing such desalination plants upto 4,500M^3 /day (1 million gallons/day) capacity. On the basis of experience with both the plants, a combined VTE-MSF pilot plant of 250M^3 /day capacity is being designed. BARC has also submitted a feasibility report to the Government of Gujarat for setting up a 4,500 M^3 /day MSF plant at Kandla. It has also provided technical consultancy service to the BHEL, enabling the latter to offer to build 1200 M^3 /day and 2,400 M^3 /day desalination plants in Tanzania. Similar consultancy service has been offered for setting up a 1,800 M^3/day

MSF desalination plant at Mithapur (Gujarat).

Besides these jobs, design work on a 2 tonne/day flash type, and 3 tonne/day vapour compress type ship-borne desalination plants has been completed and a 6M³ /day reverse osmosis brackish water desalination plant fabricated and installed at VEC, Calcutta

Electrothermal Phosphorus: The Phosphorus Pilot Plant at Trombay was operated and various systems reviewed. Modifications required to improve performance are being carried out. There is considerable demand from entrepreneurs for the technical knowhow related to elemental phosphorus production. Project reports are currently being prepared for two 2,500 tonne/year plants. Studies relating to the utilisation of the byproducts from the phosphorus plant, as also on various integrated schemes for the production of fertilizers, are being carried out. Research and

Central Workshops, BARC. Tube-to-tube sheets welding of the R-5 calandria with minimum distortion, using electron beam welding technique.



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development work on the making of carbon bricks has been completed.

Electrolytic Hydrogen: A high pressure, high current-density, advanced portable electrolyser unit of 8 KW (1500 litres per hour of hydrogen production capacity) has been fabricated and installed. A proposal for a 1 tonne/day capacity hydrogen plant has been submitted.

A solar boiler of 15 to 20 KW capacity is being fabricated under a solar energy utilisation study.

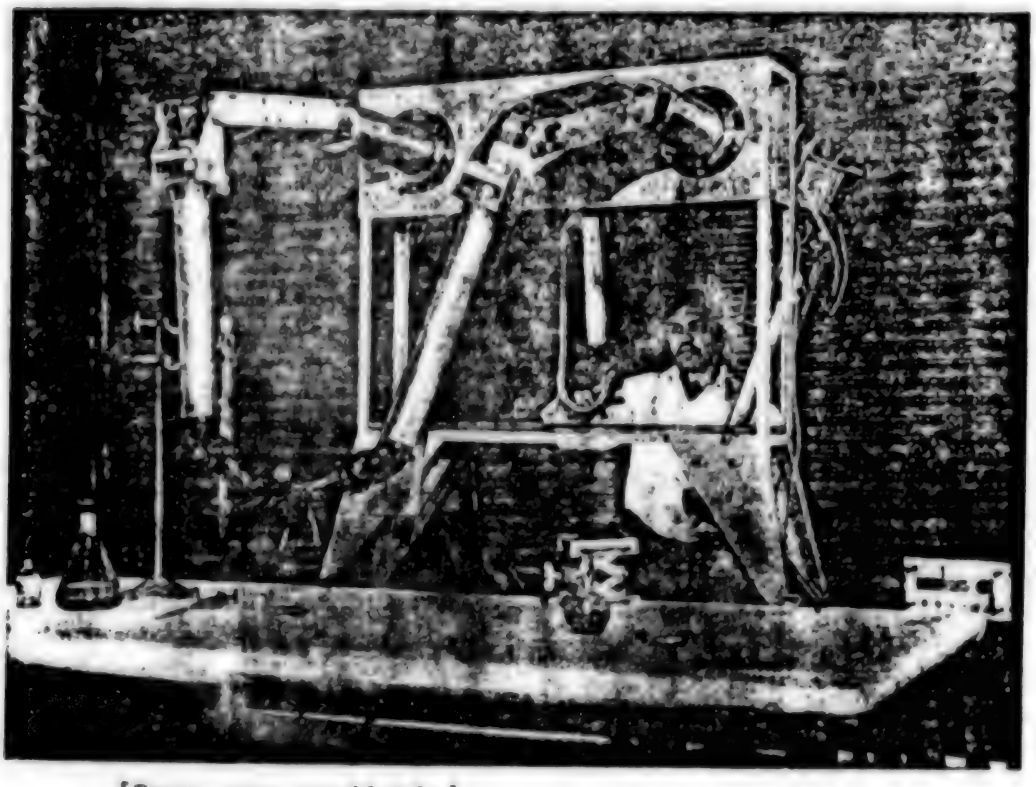
Central Workshops

The value of the items manufactured and services rendered during the year at the workshops is over Rs. 350 lakhs.

A new landmark was achieved by the CWS with its carrying out of tube-to-tube sheets welding of the R-5 calandria with minimum distortion, using the electron beam welding technique. The technique of localised vacuum employed in this case has been used for the first time in India,. Some of the significant jobs completed are : water-cooled thermal shields, fuel transfer system components for MAPP I & II, high pressure heat exchangers for heavy water projects, material and personnel airlocks for FBTR.

Fuelling machines for MAPP II are in an advanced stage of assembly. Development work on remote handling equipment like power manipulator, extended reach manipulator and periscope for WIP was taken up. An automatic technetium generator, widely used by RMC, and an automatic fraction collector with ultra-violet absorption meter, used

Master slave manipulator, designed and made by the Central Workshops of BARC.



for research work in the life sciences, were developed as part of the import substitution effort.

Computer Services

The BESM-6 Computer was operated round-the-clock with a machine availability of better than 97%. Over 400 users from BARC and other DAE units are being provided with 700 hours of usage per month. The system processes 250 jobs daily at a CPU efficiency of better than 76%. The daily usage of CPU is between 19-20 hours. The turn-around-time has been longer because of the very heavy usage.

H400 Computer. The machine availability has been better than 93%. The tape-to-tape conversion facility attached to the system was very extensively used for conversion of tapes by various users in BARC, and by users from BSF, Indian Statistical Institute, Calcutta, Computer Centre, New Delhi, and the Reserve Bank of India.

Library and Information Services

The Library holdings now stand at nearly 108,000, comprising 62,000 books and 46,000 bound volumes of periodicals. The Library receives 1,460 periodicals, of which 1,162 are subscribed to, the rest being received gratis on an exchange basis. The Depository Library now has some 450,000 scientific and technical reports, besides some 32,000 reprints of scientific papers. To this large collection, one of the largest in the world in the nuclear field, some 30,000-40,000 reports are added annually.

During the year, 85 technical reports embodying the results of research and development work done in the Centre, and the proceedings of symposia, conferences etc. were brought out.

Translations were done from Russian, German, French, Japanese, Spanish and Italian languages at the request of scientists and engineers. Nearly 200 requests for translations were complied with. The Section brings out a tri-monthly entitled 'Translation Bulletin', embodying bibliographic details of the translations done during a quarter. Copies of this bulletin are widely distributed. Courses are being conducted in German, Russian and French languages for the benefit of BARC scientists and engineers. Interpretation service was also provided on a number of occasions. Short-term training was imparted to a number of personnel from other organizations and institutions in library operations and computer handling of information.

Activities were continued in connection with India's participation in the computer-based International Nuclear Information System (INIS) established by the IAEA at Vienna in May 1970. During the year, 1,060 items published in India and falling within the subject-scope of INIS were 'inputted'. India has so far fed 7,030 items to the System, amounting to about 2% of the items in the INIS Data Bank.

The computerised information services, such as selective dissemination of information, compilation of 'Bibliography of Current Reports', and retrospective literature searches were continued. At present, some 45,000 bibliographic references are available on machine-readable form. Using the DEC-10 computer of the NCSDCT, it is proposed to use shortly the INIS output tapes for SDI, and literature search services at the national level under the NISSAT programme. The programmes are written in COBOL.

Personnel and Training

The strength of the Centre, (including the VEC Project) on February 28, 1979

was 12,380, comprising 3,317 scientific, 5405 technical, 1,216 administrative and 2,442 general maintenance and auxiliary staff.

During the period from April 1978 to February 28, 1979, 167 scientists were deputed abroad for participation in international conferences, symposia etc. 30 scientists were deputed abroad for scientific visits / training / study tours under bilateral agreements, and 13 more are expected to be deputed till March 31, 1979. The services of 3 scientists were placed at the disposal of the IAEA as the Agency's experts, and 2 scientists were deputed to render expert services under bilateral agreement; 2 more are expected to be deputed shortly. 8 scientists were granted leave for post doctoral work abroad. 16 scientists have completed their training, and 6 are undergoing training at IIT's and IISc, Bangalore.

112 scientists of this Centre have been accorded the status of University teachers by various universities.

Under the collaboration scheme between BARC and the University of Bombay, 32 students are currently doing research work leading to the MSc./Ph.D degree. So far, 17 students have qualified for the award of M.Sc./-Ph.D degree. Under the Faculty Improvement Programme of the University Grants Commission, 3 lecturers are doing research leading to Ph.D in the Centre.

One hundred and thirty-seven graduates in science and engineering successfully completed the Twenty-first Course of the Training School which was conducted from August 1977 to July 1978. They were absorbed as scientific officers and engineers in BARC and other units of the DAE. One hundred and sixty-one young graduates in science and engineering, selected on an all-India basis, joined the Twenty-second Course of the Training School which commenced in August 1978.

Reactor Research Centre

The activities at the Reactor Research Centre cover a wide spectrum, ranging from design, research and development work, to construction of the Fast Breeder Test Reactor (FBTR), and associated facilities.

Fast Breeder Test Reactor. The civil works for the buildings to house the reactor, turbine, steam generator, controls, service units etc. have been completed, and construction of the maintenance block is in progress.

There has been good progress in the fabrication of the various plant components in the suppliers' factories. The reactor vessel has been fabricated and assembled, and is ready for factory erection test. Substantial progress has been achieved in the manufacture of intermediate heat exchangers, inlet and outlet pipes for the reactor vessel, and pipes and bends for the sodium primary circuit. Fabrication work on important components like sodium pumps for the primary and secondary systems, control rod drive mechanisms, core cover plate mechanism and control plug, has also made good progress. The first control rod drive mechanism made in India was successfully tested at the Centre's Engineering Laboratory. The entire instrumentation and control system for the reactor has been ordered as a package from the Electronics Corporation of India Ltd, Hyderabad.

The safety vessel for the reactor, made of special quality imported carbon steel and fabricated at the Centre, has been

installed in position. The reactor vault is now ready for the reactor vessel and its internals. A very critical item, the stainless steel grid plate and diffuser, made in France, has been received at site and work has been taken up for fixing the neutron shields on it. The structure for mounting secondary system sodium pumps, as well as other components, has been erected in position in the steam generator building.

The present projections are that the construction phase of the project will be over by 1980, and commissioning of various systems leading to criticality would be taken up from them onwards.

The civil works for the Radiometallurgy Laboratory are almost complete. On the Materials Development Laboratory, about 80 per cent of the civil works is over.

The R & D work of the Centre has resulted in the development of a number of instruments/equipments, some of which are not readily available in the country. Such items, developed, or in advanced stages of development, include (i) an image processor for processing X-ray and neutron radiographs, (ii) high-impedence conductivity meter, and a potentiostat for corrosion studies, (iii) a microprocessor based system for monitoring data from a battery of creep testing machines, (design work in progress), (iv) a sophisticated box-car integrator, suitable for many pulse applications. This instrument has been used to improve currently available techniques for non-destructive ultrasonic testing. In particular, it has been shown that this system could be used for testing cast iron. (v) an instrument that will monitor the long time movements, if any, of the FBTR vessel. (vi) Oxygen sensors for monitoring oxygen in inert gases in the range of 10 per cent to less than 0.1 ppm. (vii) As part of safety research at the Centre, an aerosol photometer was custom built for detecting steam leaks from fuel channels in RAPS reactor, (viii) a Bonner sphere neutron dosimeter was built and is in use, and a lithium-iodide based fast neutron spectrometer was developed and used for measuring spectra of different neutron sources.

Tata Institute of Fundamental Research

A 400 KV ion accelerator has been built, and ion beams of several elements like carbon, nitrogen, oxygen, chlorine, argon, copper and iron have been obtained. A triplet electrostatic quadrupole lens has been designed and made for final focussing of the beam onto the target chamber. The ion beam will soon be used for research work.

An engineering model for the detector developed for the TIFR-ISAC X-ray Sky Monitor, to be launched on the second Indian satellite, has been tested. The prototype payload is currently undergoing qualification tests at ISRO's Satellite Centre, Bangalore. The satellite is expected to be launched in April-May 1979.

A rocket payload, developed for detecting ultrasoft X-rays, originally meant to be flown on the Centaur rocket, but dropped because of excess weight, has been modified to suit the India-made RH560 rocket. The first flight of RH560 is due within the next few months

X-ray astronomy studies were carried out with satellites. Using U.S. satellites, accurate positions of X-ray sources were obtained and their properties studied

A balloon flight was carried out under a collaborative programme between the

TIFR and the University of Calgary, Canada for observing the X-ray emission of Her X-1 in 20-100 KeV range. This experiment was repeated to observe X-ray emission from newly discovered Gamma ray sources.

A 30 cm infra-red telescope, Mark I, will be flown shortly on a balloon; it was flown earlier in November 1978 but no astronomical data could be gathered as its far infra-red detector failed. Another telescope of 75cm aperture, Mark II, and associated orientation platform has been assembled and is scheduled for being flown onboard a balloon later in 1979. This telescope is capable of making observations with a spatial resolution of better than 1 arc min.

Cosmic Ray Studies

Highlights of this year's studies on cosmic rays include detection, for the first time, of relativistic iron group nuclei in the new plastic detector, CR-39, flown in a balloon. Studies of low energy cosmic rays made from detectors exposed in the Skylab have confirmed the hypothesis of a new component of cosmic rays with partially ionised states. Plastic detector studies of solar cosmic ray heavy nuclei have been carried out using detectors exposed in rockets. Currently, solar cosmic ray heavy nuclei are being studied in one of the most intense solar flare events (of August 4, 1972), to obtain the abundances and energy spectra of rarer nuclei in solar cosmic rays.

At the Radioastronomy Centre at Ootacamund, to continue the search for pulsed ultra high energy cosmic rays from pulsars, two additional large area mirrors, each of area 1.8 m^2 were added to the existing Gamma Ray Telescope of 10 mirrors at the Centre. Six more large area mirrors have been acquired from the Smithsonian Astrophysical Observatory, USA, and mounted at Ooty. In view of the variable nature of the sources, it has been decided to continue observations for another 3 years.

At the Kolar Gold Mines in Karnataka, the search for new particle events and anomalous showers of high energy, which have been reported in earlier experiments, was continued with a large scale detector at a depth of 3,375 hg/cm^2. Data collection and analysis of air showers at a depth of 270 m underground for recording muons of energy 220 GeV were continued.

At the Radioastronomy Centre, Ooty, an intensive programme was started for locating new pulsars. For this purpose a high sensitivity 144 channel receiver system was built and connected to the Ooty radio telescope. In the very first session of observations, 3 new pulsars were found. Calculations show that this programme should yield several new pulsars in the near future and thus increase substantially the number of known pulsars. Searches have been planned in specific regions of our galaxy of special astrophysical significance.

For the first time, a halo around a pulsar with a size of one light year was detected using the method of lunar occultation.

Under a grant of Rs. 5 lakhs from the Indian Space Research Organisation under its Respond Programme, the entire 530 m long dipole array, consisting of 968 dipoles, is being replaced by a new array with low loss diode phase shifters developed at Ooty. As a result of these changes, the sensitivity of the Ooty radio telescope is expected to increase by as much as 4 times, which would enable starting of new, exciting, research programmes. Also,

this work on the phased-arrays will be of value to the rapidly steerable antennas needed in other fields in India.

Work on expansion of the Ooty Interferometer system was taken up. This instrument, called the Ooty Synthesis Radio Telescope (OSRT), will eventually consist of 13 smaller low cost antennas spread around the Ooty Radio Telescope at various distances upto 10 km. The outputs of these antennas will be combined with that of the Ooty radio telescope using sophisticated electronic links to form a synthesis radio telescope. The first phase of the OSRT, consisting of 8 antennas spread upto 4 km, is nearing completion, and will be in operation during 1979-80. Apart from being of low cost, a noteworthy feature of 5 of the antennas is that they were fabricated by a small workshop at Mettupalayam, and the design and erection work was done by the Radio Astronomy Group at Ooty. When completed, the OSRT will be one of the largest synthesis radio telescopes in the world, and the only one operating at metre wavelengths. A PDP 11/70 computer system is being installed for analysis of data obtained from OSRT.

A novel design of a solar energy collector has been developed, and a model of the same is being fabricated for test purposes, under a grant from the Tata Energy Research Institute.

In the *Hydrology* Programme, spot measurements of radon in the monsoon air mass over the Arabian Sea have already established their usefulness in delineating the origin of the monsoon air mass. These measurements have been verified by BARC workers. The next step is to make continuous measurements of radon in monsoon air mass over the Arabian Sea to explore relationship, if any, between radon content and monsoon activity. The experiment will be carried out during the 1979 Monex Expedition.

Hot water emerging from springs carries sizeable amounts of radon. Spot measurements were made in several springs on the western coast of India. Continuous measurements were made for several years at Ganesh Puri and Sathville with a view to observe relationship, if any, between, radon content and seismicity. Since quiet conditions largely prevailed in this region, the experiment is now being conducted in the seismic north-eastern region of the country.

A new concept for creating groundwater reservoirs suitable for the Indian environment, and a feasible scheme to achieve the same, has been proposed. The time is now ripe for its implementation. Negotiations are going on with the authorities in the U. P. Irrigation Department in this connection.

Exploratory measurements of methane in groundwater have been initiated with a view to observing their utility in oil exploration. This is a new problem (not attempted by anyone as far as is known). It may grow into a full scale project.

In *Solid State Electronics*, some of the work taken up earlier, like that on PIN diodes, V/UHF thin film modules etc. for Defence was successfully completed.

Since the main area of development is towards the realisation of large scale integration, the crucial activities connected with it, namely computer design for graphical layout, were completed. This work required development of both hardware and software. An imported system with less capabilities would have cost Rs. 40 lakhs. Other programmes, like device characterisation, logic

simulation are being worked out. Exhaustive experiments have been conducted on some of the silicon oxide growth problems.

Fundamental studies on interface states on GaAs and on silicon are being carried out. Amorphous silicon is a potential material for inexpensive solar cells. Fundamental studies connected with the growth of amorphous silicon and the interaction of hydrogen are being carried out.

In the area of *Microwave Engineering*, as part of the Special Microwave Products Unit (SMPU) set up under the Department of Electronics, two major systems for the Monsoon experiment, MONEX 79, namely Radio Theodalites and Data Processing, Display and Storage attachments to Weather Radars have been developed for supply. A variety of special microwave products, such as microwave integrated circuits, TR limiters, components for Satellite Earth Stations, components for scientific instrumentation, and components and subsystems for Radar and Communications are being developed and supplied in the limited quantities in which they are required for developmental activities and for strategic equipments.

In the area of *Computer Research and Development*, work on computer recognition of human speech was continued. Extracting the fundamental frequency (or pitch) is an important problem in speech analysis; it is often necessary for speech synthesis, speech recognition and for studying human speech perception. A new technique for extracting pitch has been developed which works well for different speakers as well as for speech recorded under noisy conditions.

The *National Centre for Software Development and Computing Techniques* has been operating its DEC System 1077 time-sharing system as a national facility. Due to heavy demands on its services, the system is currently overloaded; the main and disc memories of the system are therefore being augmented, the equipment being procured through the UNDP. There are now over 300 major users of the system, who use the facilities either at the Centre or through the remote link from the VJ Technical Institute at Matunga, Bombay.

The first one-year course for computer professionals, conducted jointly with VJTI, is over and, based on experience with this course, a second course is being started.

Work on computer graphics and computer-aided design has centred around the commissioning of the on-line model-making machine, and the design of a new graphics support package, SIGN. A comprehensive text preparation and photo-typesetting package has been completed and is in regular use.

In co-operation with the P and T, and the Space Applications Centre, Ahmedabad, work is in progress on using satellite links for computer-based digital communication. This work is a direct outcome of the earlier work on computer communications. The Close-Coupled Network of TDC 316 computers is due to be moved shortly to the Indian Institute of Technology, Powai. Work continues on the linear programming system, FLIPS, and the programme manipulation laboratory.

In the area of *Dental Research*, results of a ten–year follow-up survey started in 1966 showed that oral cancer and precancerous lesions almost never occurred among those who did not have

any kind of tobacco habit. A colour film on the subject, specially made by TIFR for this purpose is also being shown to the villagers. This film won the President's Award as the Best Educational Film of 1977; it has been donated to the Films Division.

The *Homi Bhabha Centre for Science Education* has started publishing material developed during the last 3 or 4 years for primary schools, in the form of books. The Centre is also working on developing teaching aids, like filmstrips, for schools.

To promote exchange of expertise and knowhow among innovators and educationists, a state level conference on Science Education was organised by the Centre at Khiroda, a small village in Jalgaon district, Maharashtra, in January 1978. Efforts are now being concentrated on curriculum development work at the secondary school stage, along with field interaction with schools in Bombay (B.M.C. schools), as well as with those in the rural areas of Jalgaon district.

TIFR Balloon Facility, Hyderabad

Four balloon flights–two for X-ray Astronomy, and one each for Gamma Ray and Infra–red Astronomy experiments–were successfully launched to 30 to 39 km. on plastic balloons with volumes of 50,000 m^3 to 110,000 m^3. In addition, three balloon flights were made to conduct launch trial tests for the new launch vehicle. The new launch vehicle, built around a 12 metric tonne truck, is being tested to launch, in the downwind configuration, payloads upto 1,000 kg and of sizes upto 1.5 metre square and 4.5 metre height.

Special load-tapes for stratospheric balloons have been successfully fabricated. It is proposed to manufacture them in large quantities for regular use.

Interaction with Bombay University

The School of Mathematics has been collaborating with the University of Bombay in the latter's centre for Advanced Training and Research in Mathematics. The Institute is a recognised centre of the University of Bombay where students work for the M.Sc. and Ph.D. degree in Mathematics, Physics (Theoretical and Experimental), Molecular Biology, Physical Chemistry and Computer Science. 60 scientists of the Institute are recognised teachers of the Bombay University for the Ph.D. degree and 4 for the M.Sc. degree. During this year 9 members obtained their Ph.D. degree on the basis of research carried out at the Institute. Thus far, a total of 183 scientists have obtained their Ph.D. and 42 their M.Sc. degrees through research carried out at the Institute.

The UGC has undertaken a more comprehensive Faculty Improvement Programme. The Institute is extending its facilities to teachers in the affiliated colleges and, accordingly, in the academic year 1978–79, four teachers are availing of the facilities.

Prof. M. S. Raghunathan of the Institute received the Shanti Swarup Bhatnagar Award for 1977. Dr. V. V. Deodhar was awarded the Young Scientist's Medal (Mathematics) for 1978 by the Indian National Science Academy, New Delhi.

Saha Institute of Nuclear Physics

In the area of radiochemistry, simple methods are being devised for separating mixtures of suitable radionuclides. Organic cation exchangers have been used for separating rare earths using different eluants. Various oxidation states of sulphur have also been separated by using an organic anion ion exchanger.

In radiation chemistry, the study of metal complexes of amino–polycarboxylic acids has revealed many interesting features hitherto unknown, which are useful in predicting the formation of new species, as well as in formulating the radiolytic models of reaction mechanism in metal complexes in general.

Biological functions, in terms of their structural and conformational features, crystal and molecular structures of a number of biologically important molecules (including drug molecules), and antibiotics have been studied using X–ray crystallography and other physicochemical methods. Some features have been observed which might play an important role in structure-activity relationship. In protein crystallography, attempts are being made to grow larger salt-free crystals of Abrin, a protein of plant origin, for X-ray crystallographic investigations; crystallisation of two other proteins from animal sources, a–amylase and ovalbumin, is in progress.

In studies of enzymes, interesting results have been obtained regarding the assay method of a-amylase. It has been observed by repeated application of chromatographic and spectrophotometric techniques that the usual assay method for a-amylase with 3, 5 dinitrosalicylic acid is an erroneous technique. This is a significant contribution in analytical biochemistry. The isolation and purification of lectins (with little or no toxicity) from plant sources is well under way. In physical biochemistry, the aggregational properties of structural proteins have been studied. A general methodology for precipitating obliquely striated fibrils of collagen has been suggested. This would help to throw light on the factors which influence the trogocollagen molecules to aggregate in this peculiar fashion.

Facilities have been developed for research in the emerging discipline of Membrane Biology. New and interesting results have already been obtained. Ultraviolet and sunlight have been shown to cause peroxidation of the fatty acid hydrocarbon chains in the membrane's lipid bilayer, which results in leakiness of the membrane. The products of lipid peroxidation resulting from exposure to radiation have been estimated. The radiation damage was found to be higher when the dose rate was lower, and a protracted radiation dose was found more effective than a shorter, more intense one.

Serum isolated from goat blood and purified in the laboratory has been found suitable for the growth of mammalian cells in culture.

Mutations have been induced and are being analysed in cultured Chinese hamster cells exposed to ultraviolet light, or treated with tetracycline.

Under the instrumentation development programme at the Institute, the following works are in progress:

(i) Modification of the present neutron generator to make it a high intensity 14 MeV neutron source.

(ii) Building of a set-up for measurement of nuclear lifetime in the range of 10^{-12} to 10^{-15} sec. by Recoil Distance and Doppler Shift Attenuation techniques.

(iii) A particle identification system using CO_2 gas proportional counter and CsI(Tl) detectors to measure the energy spectra of the emitted charge particles in nuclear reactions.

Tata Memorial Centre

Tata Memorial Hospital

There was an increase of 5 percent in the number of new patients examined in the Hospital's Clinic during the year, compared to last year. The figure for this year is 17,233. A total of 10,359 operations were performed; and 5,288 patients were admitted into the wards as inpatients. Of this number, 388 were admitted in the new chemotherapy wards given by the Indian Cancer Society, and commissioned last year.

Around 500 patients were treated daily in the Department of Radiotherapy; 70 to 80 patients received intracavitory treatment every month. After-loading applicators were increasingly utilised for beta therapy; and the hospital will soon receive special caesium 137 radiation sources for this purpose.

A new Cobalt 60 therapy unit, a 12 MeV Linear Accelerator, computerised treatment planning system, and a simulator are expected to be installed by mid-1979. With this increase in the number of therapy units, it will be possible to treat a greater number of patients daily, and with better therapeutic efficiency. The hospital continues to act as a centre for imparting practical training in Health Physics to students attending the special courses conducted by the Bhabha Atomic Research Centre.

An additional major operation theatre was commissioned during the year, and the endoscopy and minor operation theatres were reorganised. An A. O. oximeter, to assess the oxygen saturation of the blood in patients undergoing prolonged major surgery, was added to the Anaesthesia Department. The first continuing education course in Anaesthesiology was conducted at the Hospital.

Microsurgery, a new advance in surgical technique, was undertaken for the first time during the year. A special microsurgical theatre and ward are due to be commissioned during the latter half of 1979. There are plans to organise clinical research projects on Genito-Urinary Cancer in a like manner, and to set up an advanced Gastro-intestinal endoscopy centralised unit at the Tata Memorial Hospital. The WHO collaborative research project on End Results Reporting in Breast Cancer is continuing in association with French and Russian Cancer Centres.

During the year, several clinical research studies were initiated. The studies included estimation of drug levels in the blood of patients receiving anticancer drugs, and further characterisation of acute lymphoblastic leukaemia in order to undertake more aggressive therapeutic modalities. Immunotherapy is a fast developing new mode of treatment for cancer, and controlled trials have been initiated to study the usefulness of Coryene bacterium Parvum in Indian patients. The role of combination therapy, using multiple drugs, is being tested through clinical trials.

Subsequent to the shifting of certain departments to the new annexe, the operation theatre wing and the semi-private ward in the old building, are being expanded.

Cancer Research Institute

Investigations of human cancers, particularly the types frequently seen in the Indian population, formed the major activity at the Institute. A prospective study of 14,000 workers (7000 White collar and 7000 Blue collar), indicated that the incidence rate of cancer is 100 per 100,000 population in the age group 35 and above. Epidemiological

studies of animal cancer showed the prevalence of horn and eye cancer in certain cattle breeds from Gujarat and South India; this aspect is being intensively studied. Chemical analysis of *bidi* smoke extracts indicated a high level of tar and nicotine, compared with that obtained from ordinary cigarette smoke. Carcinogenic potential of Isoniazid, a basic drug used in the treatment of tuberculosis, was demonstrated by animal experiments.

Bio-electrical changes in the cancer cell membrane were studied with regard to its potential for producing metastases. It was observed that tumour metastases took place when there was increased negative charge on tumour cells and the availability of calcium binding sites on the target organ.

Studies undertaken on leukaemia related to immunology and chromosomal patterns. Short term experiments on normal and leukaemia leukocytes revealed a close relationship between their locomotive behaviour and intra-cellular glycolytic activity.

Nuclear Magnetic Resonance studies (NMR) showed that the nuclear fractions of cancer cells were responsible for elevated T1 values in malignant cells. A quick *in vitro* assay which can predict the response of breast and ovarian cancers to hormones and drugs was developed.

Several indigenous plant extracts were screened for anticancer activity, and soil samples were screened for fungi which can produce antibiotics having anticancer activity.

The Institute trained 5 graduate and 14 post graduate students during the year. The Institute also hosted an international symposium on Population Structure and Human Variation, and the Annual Conference of the Indian Society of Cell Biology.

PUBLIC SECTOR UNDERTAKINGS

Three public sector undertakings under the Department *viz* the Indian Rare Earths Ltd., the Electronics Corporation of India Ltd. and the Uranium Corporation of India Ltd. are discussed here. The IRE operates the mineral sands industry in Manavalakurichi and Chavara, and the rare earths industry at Alwaye, besides producing thorium products at Trombay. The ECIL manufactures a variety of nuclear and non-nuclear electronic instruments and equipment, and the UCIL develops the Uranium Mine and operates the Uranium Mill at Jaduguda, in Bihar.

Indian Rare Earths Ltd.

During 1978–79, the sales turnover of the Company is expected to be of the order of Rs. 9.6 crores. Of this turnover exports account for approx Rs. 4.6 crores. The respective figures for 1977-78 are Rs. 8.7 crores and Rs. 4.9 crores. The sales would have been higher but for the shortage of monazite, which kept the Rare Earths Plant under-utilised. A Pre-concentrator Facility is therefore being set up at Manavalakurichi in Tamil Nadu to improve the feedstock of the beach sands separation plant, and help in increasing production of monazite.

The net profit after tax in 1977–78 was Rs. 93.7 lakhs. During 1978–79, the net profit after tax may increase to approx Rs. 110 lakhs.

Work on the Orissa Sands Complex (OSCOM) Project, near Chatrapur, Orissa is progressing satisfactorily. Major design work for the various plants has been completed, and plant machinery are in the pipeline. Civil work on the plant complex has started. The project is expected to go on stream by mid 1981. The Government has so far released funds to the tune of Rs. 11.7 crores upto March 31, 1978, and about Rs. 4 crores will be released during 1978-79.

The Board of Directors of the Company has been reconstituted with the induction of new Directors who bring with them wide experience in the varied fields of management.

The Company was once again selected for an award for best export performance in the group 'Basic Inorganic & Organic Chemicals' for 1977-78, instituted by the "Basic Chemicals, Pharmaceuticals and Cosmetics Export Promotion Council, Bombay." This is the 8th prestigious award the Company has bagged during the last few years for its export performance.

The Electronics Corporation of India Ltd.

During 1977–78, the Corporation incurred a loss of Rs. 105.42 lakhs, after providing for depreciation of Rs. 226 lakhs, interest of Rs. 254 lakhs on loans and borrowings, and expenditure on social facilities of Rs. 46 lakhs. The loss was adjusted against the brought for-

ward surplus of Rs. 1.98 lakhs, and General Reserve. The unfavourable result was due to the provision of liability made for implementation of revised pay scales of the employees for the period January 1, 1977 to March 31, 1978, and adjustment of certain other items of expenditure pertaining to the earlier years.

The working results of the Corporation for the year 1978–79 are expected to result in a loss of Rs. 119 lakhs after providing for depreciation of Rs. 236 lakhs, and interest of Rs. 273 lakhs on loans and borrowings, which will be adjusted against the General Reserve. However, for the year 1979–80, the production and income levels of the company are expected to be of the order of Rs. 5,149 lakhs, and Rs. 5,278 lakhs respectively, and the working results are expected to yield a profit of Rs. 80 lakhs.

During the year 1977-78, the Corporation supplied approx Rs. 81 lakhs worth of instrumentation/equipment to the various nuclear power projects and the heavy water projects, and nuclear test and measuring instruments worth Rs. 51 lakhs to various units of the Department of Atomic Energy.

The Company also supplied digital computers costing approx Rs. 35 lakhs to DAE units.

The instruments and systems developed at ECIL during the year include Fast Scanner, Fluorimeter for uranium analysis, Bed-side Monitor, Storage Myograph, Ultrasonic Rail Tester, Co-ordinate Printer for aviation purpose, Microwave Oven, 'X' Band Signal Generator, Digital Printer, Programmable Logic Controllers, 10' Spun Dishes, Automatic Warning Systems, and Infra Red Intruder Alarm Systems etc. On the *Components* side, the Corporation has developed and produced Microwave Veractor Diodes, Temperature Compensated Zeners, Bulk Metal Resistors, BU 205 Transistors, etc. In the *Computer Field*, the Corporation developed and produced Micro Computer based data loggers, and a new model of the Analog Computer AC-20H. Magnetic Disc Versions of TDC-312 EDP Systems, EDP Systems around TDC-316, Real Time Computer Systems around TDC–332, and Multi–Terminal Data Entry Systems to replace off-line data preparation work are under development.

Uranium Corporation of India Ltd.

The commissioning of stage II of the mine at Jaduguda has opened up more levels, and consequently, more number of working faces. The grade of ore is also likely to be higher as bore-hole core analysis has shown that the content of uranium in the ore is higher at deeper levels. Production of uranium concentrates is therefore expected to increase during the year. Optimum production however has not been possible because of frequent power interruptions and restrictions.

The Byproduct Recovery Plant for recovering copper and molybdenum minerals, and the Uranium Recovery Plant at Surda are working satisfactorily. Work on expansion of the latter to treat all the copper tailings available from the South Bank Copper Beneficiation Plant of Hindustan Copper Ltd. is in progress. Pilot plant scale investigations for upgrading low uranium values present in the Rakha Copper Concentrator tailings of HCL have been completed. Based on these investigations, a techno-economic feasibility report has been prepared for setting up a full-scale plant to treat the tailings.

The pilot plant facility for recovery of magnetite from Jaduguda mill tailings has been modified and augmented to increase production of magnetite. A full-scale magnetite recovery plant is expected to be commissioned next year.

The Company has formulated an ambitious expansion programme for implementation during the current Five Year Plan period.

OTHER ACTIVITIES

The following units/activities of the Department are discussed: Directorate of Purchase and Stores, Civil Engineering Division, Directorate of Estate Management, Financial Assistance, Contributory Health Service Scheme, Planning and Analysis Group, Publicity, Use of Hindi, Atomic Energy Schools, and International Relations.

Directorate of Purchase and Stores

Purchase Units: The volume of work handled by the Purchase Units of the Directorate during 1978–79, as compared to 1977–78 is indicated below:

Sl. No.	*Description of the item*	*1977–78*	*1978–79*
1.	Number of indents received	42,664	44,476*
2.	Number of orders placed	45,129	45,139*
3.	Value of purchases made (in lakhs of rupees)	6,080	6,909*

(*Figures have been projected on the basis of actual workload till end Dec. 1978)

Some of the major contracts concluded by the Directorate during the year under report are:

Sl. No.	*Description of the item*	*Project/ Unit*	*Value (in lakhs of rupees)*
1.	Surface type Steam Condensor	N.A.P.P. I & II	212
2.	6.6 KV Switchgear	–do–	162
3.	Condensor Cooling Water Pump Motor Unit	N.A.P.P.	161
4.	Plate type Heat Exchangers	N.A.P.P. I & II	157
5.	Bioler Feed Pumps	N.A.P.P.	125
6.	Extrusion Press Runout Table	N.F.C.	88

7.	Shielding Blocks	F.B.T.R.	62.93
8.	Secondary Cycle Pumps	N.A.P.P.	58.57
9.	Water Chiller Packages	N.A.P.P.	55.001

Transport and Clearance: The Directorate has its own unit for clearance and transportation of materials pertaining to various Projects/Units of DAE. During the year it cleared over 10,000 consignments at Bombay, and 1923 consignments at Madras.

Some of the important, and heavy consignments cleared and transported on behalf of the various Projects/Units during the year are :

Sl. No.	*Description of the item*	*Weight (in M. Tonnes)*	*Transportation details*
1.	Roller Hearth Furnace	342	From Bombay Docks to N.F.C. Hyderabad
2.	Carbon Steel Plates	325	From Bombay to Bhopal (BHEL) by Rail
3.	Seamless Carbon Steel Pipes	163	From Bombay Docks to Project Stores, Trombay
4.	Carbon Steel Pipes	135 91	From Bombay to Narora by Rail
5.	Cold Pilger Mill	133	Bombay Docks to NFC, Hyderabad
6.	Stainless Steel Billets	88	Bombay Docks to Bharat Forge Co., Pune
7.	IRIS-80 Computer	17.43	By chartered aircraft from Paris to Calcutta, and from Airport to VEC Site.

Stores

The total number of receipts handled by the Stores Units of DPS and the number of issues made during the years 1977-78, and 1978-79 are given below :

Sl. No.	*Description of the item*	*1977-78*	*1978-79*
1.	Number of Receipts	2,66,395	6,75,982
2.	Number of Issues	2,62,162	7,35,999

The work relating to codification of capital items held by various divisions/ sections in BARC has been completed and the information is being fed to the computer.

Construction of O & M Warehouse (Phase I) at Narora is being taken up. An Inflammable Stores Building has been built at Narora. A new stores building, having an area of 1400 sq. m. has been constructed for storing materials for the R-5 Project, Trombay. An Inflammable Stores Building is proposed to be constructed at RRC, Kalpakkam, similar to the one at BARC, Trombay.

The total revenue earned by the Central Stores Unit at Trombay by way of sale of scrap during the calendar year 1978 was approx. Rs. 32 lakhs. Substantial revenue on this account has also accrued from various other Stores Units of DPS.

Civil Engineering Division

The Division completed construction of 344 flats of various categories in the Trombay Township during the year.

The Division also completed extensions to the IInd and IIIrd Primary Schools at Trombay, and is taking up construction work on the Sector Market, a block of 10 class rooms, and a multi-purpose hall for the IInd Primary School, shortly. During 1979-80, work is expected to start on a Junior College, Community Centre, Open Air Theatre, Club House, and a Swimming Pool in the Township.

Construction work on the Department's Secretariat building in the Bombay City area, started in April 1977, is expected to be completed shortly. In addition, work on a hostel block at TIFR, started in April 1978 is expected to be completed by mid-1979.

Outside Bombay, the Division has completed the following projects: Construction of extensions to the Laboratory and Hostel Buildings at the Radio-astronomy Centre, Ooty; Extensions to the ground and first floors of the laboratory wing of the VEC at Calcutta; Phase II of the building for the SINP, Calcutta; work on three buildings for the Atomic Minerals Division at Hyderabad, which was started in February 1977, is expected to be over soon.

Besides DAE buildings, the Division is also handling construction work on a building for the Regional Instrumentation Centre of the University of Bombay at Kalina, a suburb of Bombay. The building is almost ready.

Directorate of Estate Management

The Directorate of Estate Management looks after allotment and maintenance of the Department's residential buildings in Bombay. During the year, it took over 232 newly constructed flats at the Trombay Township from the Civil Engineering Division and completed allotment to the Department's employees.

Financial Assistance

On the advice of the Board of Research in the Nuclear Sciences (BRNS) and its Advisory Committees, financial assistance was given during the year to universities and research institutions for work on 146 research projects relating to the nuclear sciences and allied disciplines. Fellowships were also awarded for research in the physical and chemical sciences, engineering sciences, life sciences and mathematics etc.

Besides providing financial support to the three aided institutions under the administrative control of the Department *viz.* the Tata Institute of Fundamental Research, Bombay, the Tata

Memorial Centre, Bombay, and the Saha Institute of Nuclear Physics, Calcutta, the Department made part contributions for the operation and maintenance of the Institute of Mathematical Sciences, Madras, and the Mehta Research Institute of Mathematics and Mathematical Physics, Allahabad. Financial assistance has also been given to the Indian Academy of Sciences, Bangalore, for its publication activities.

Symposia/workshops in the following areas were organised by the BRNS. and its Advisory Committees during the year : (i) Industrial Polymers (ii) Power Plant Safety and Reliability (iii) Solvent Extraction of Metals (iv) International Conference on Advances in Chemical Metalurgy (v) Plasma Physics and Magneto Hydrodynamics (vi) Nuclear Physics & Solid State Physics Symposium (vii) High Energy Physics Symposium.

The Department also provided partial financial assistance for the following activities :

(i) 22nd Meeting of the Committee for Space Research (COSPAR) 1979
(ii) Guha Research Conference-1978
(iii) International Symposium on Regulation of Gluconeogenesis
(iv) Third All India Congress of Cytology & Genetics
(v) Second Annual Conference of the Indian Association of Medical Physicists of India
(vi) Environmental Mutagen Society of India
(vii) Seminar on Current Trends in Lattice Dynamics, organised by the Indian Physics Association
(viii) 16th Annual Convention of Chemists
(ix) Mathematical Modelling and its Applications
(x) Sixth National Symposium on Refrigeration & Airconditioning
(xi) Nuclear Medicine Society - 10th Annual Conference.
(xii) Recent Developments in Mathematics and its Applications
(xiii) Annual Meeting of the Society of Biological Chemists (India)
(xiv) Third National Symposium on Cryogenics
(xv) Seminar on Engineering and Health Care, organised by the Instrument Society of India, Bangalore
(xvi) Symposium on Recent Developments in Applied Analytical Chemistry, organised by the Institution of Chemists (India)
(xvii) Symposium on Luminescence & Allied Phenomena
(xviii) Einstein Centenary Symposium
(xix) Second National Symposium on Radiation Physics
(xx) Sixth Annual Conference on Radiation Protection
(xxi) 66th Session of the Indian Science Congress-1979, at Osmania University, Hyderabad
(xxii) Fourth International Conference on Fracture Mechanism in Engineering Applications, Bangalore.

Contributory Health Service Scheme (CHSS)

The Scheme currently covers 52,000 beneficiaries. The BARC Hospital at Trombay and the dispensaries located in different parts of Bombay City and suburbs handled some 4,20,000 cases during the year. The BARC Hospital admitted 5,000 patients, and treated around 34,500 patients in its outpatient's departments. The bed strength of the hospital has been increased to 160.

Planning & Analysis Group

The Group was involved in completing

the following major assignments during the year: (1) Performance review of the public sector undertakings of the Department. (2) Organisation of a Seminar on Procurement and Vendor Performance. (3) Review of Government policies and procedures in the area of computers. (4) Pricing of the services of the Radiation Medicine Centre. (5) Preparation of the long term Isotope Applications Programme. (6) Review of the fuel expansion programme of the Nuclear Fuel Complex. (7) Costing of Co-60 manufactured by the Power Projects Engineering Division of the Department.

The Group is currently engaged in the following studies: (i) A study of the strategies, programmes and operations of the Computer Group of ECIL. (ii) A study of the organisation structure of the Nuclear Fuel Complex. (iii) A study of ECIL's proposal to manufacture Isotope Thickness Gauges. (iv) Determination of compensation for uranium payable to the Uranium Corporation of India Ltd. by the Department. (v) Design of a reporting system for the tube plants of the Nuclear Fuel Complex required for the use of the Department. (vi) Review of division-wise profitability of the Electronics Corporation of India Ltd.

Publicity

During the year, 14 exhibitions on atomic energy were organised by the Department. Of these 5 were in Bombay city, 7 in different parts of the country (mobile exhibitions), and one each at the National Science Exhibition in Moscow and the National Small Industries Fair at New Delhi.

The Department is also preparing two films, *viz*· "Nuclear Power Reactors," and "Radioactive Waste Management." The shooting of the films is over and editing is in hand. Work on two more films, namely, "In the Service of Mankind," and "Timely Action of Molecular Disorder" has been taken up.

The Department also publishes two regular external bulletins: *Nuclear India*, a monthly in English, and *Parmaanu*, a quarterly in Hindi, besides sales literature and information brochures on the programme.

Use of Hindi

233 employees from different units of the Department participated in the Hindi Teaching Scheme of the Ministry of Home Affairs; 37 employees were nominated for training in Hindi typewriting, and 5 employees in Hindi shorthand. Hindi workshops were organised in the Bhabha Atomic Research Centre, Tarapur Atomic Power Station and Rajasthan Atomic Power Project for training Hindi-knowing employees in noting and drafting. Posts of Hindi Officer were created in the Electronics Corporation of India Ltd. and the Indian Rare Earths Ltd. Hindi translators were appointed in some more units. Now every major unit of the Department has at least one Hindi translator. A large number of forms in use in various units of the Department have been printed in Hindi and English. A checkpoint was set-up in the Department to ensure that all general orders are bilingual. Various documents like gazette notifications, international agreements, administrative reports and other papers for Parliament, and Cabinet summaries and Cabinet notes etc. are prepared in Hindi, in addition to English.

Atomic Energy Schools

The Atomic Energy Education Society, established in 1969, runs schools for the benefit of the children of employees of the Department at Bombay, Tarapur, Hyderabad, Narora and Jaduguda. Ex-

cept at Narora, where the school is upto class X, all the other schools have classes from KG to class XII. The schools follow the courses prescribed by the Central Board of Secondary Education, New Delhi. The total enrolment in the schools is 8,372.

An important development during the year is the starting of a Junior College by the Society at Trombay. The college runs courses in Commerce and Science, and is affiliated to the Maharashtra State Board of Secondary and Higher Secondary Education, Pune.

International Relations

India continued to participate in all important activities of the International Atomic Energy Agency. It was designated again on the Board of Governors of the Agency for this year, the 22nd year in succession since the formation of the IAEA. This appointment is based on India's standing as one of the nine member countries most advanced in the field of atomic energy. Indian experts are participating in a number of Technical Review Committees constituted by the IAEA for preparing Safety Codes and Guides for nuclear power plants. A meeting of the Technical Review Committee on Governmental Organisations was held at the BARC, Trombay, during November 6–10, 1978. India is also playing its part in promoting nuclear technology by providing training facilities to scientists nominated by the IAEA under the latter's Technical Assistance Programme.

Dr. H. N. Sethna, Chairman of the Atomic Energy Commission and Secretary, Department of Atomic Energy led the Indian delegation to the 22nd regular session of the IAEA General Conference in Vienna during September 18–22, 1978.

Bilaterial Collaboration and Activities. A new agreement for collaboration in the peaceful uses of atomic energy was signed with the USSR on January 22, 1979. In July 1978, a memorandum of understanding on cooperation for peaceful uses of nuclear energy was signed with Libya. On March 16, 1979 an agreement on cooperation on peaceful uses of nuclear energy was signed with Yugoslavia.

A joint India–FRG Seminar, and a workshop, were held on separate occasions during the year. The seminar, on 'Trace Elements Characterisation and Analysis', was held in the FRG in October 1978 and had nine Indian scientists participating in it. The workshop, on 'Aerosols', was held at BARC during January 8–12, 1979 with 8 German scientists participating in it.

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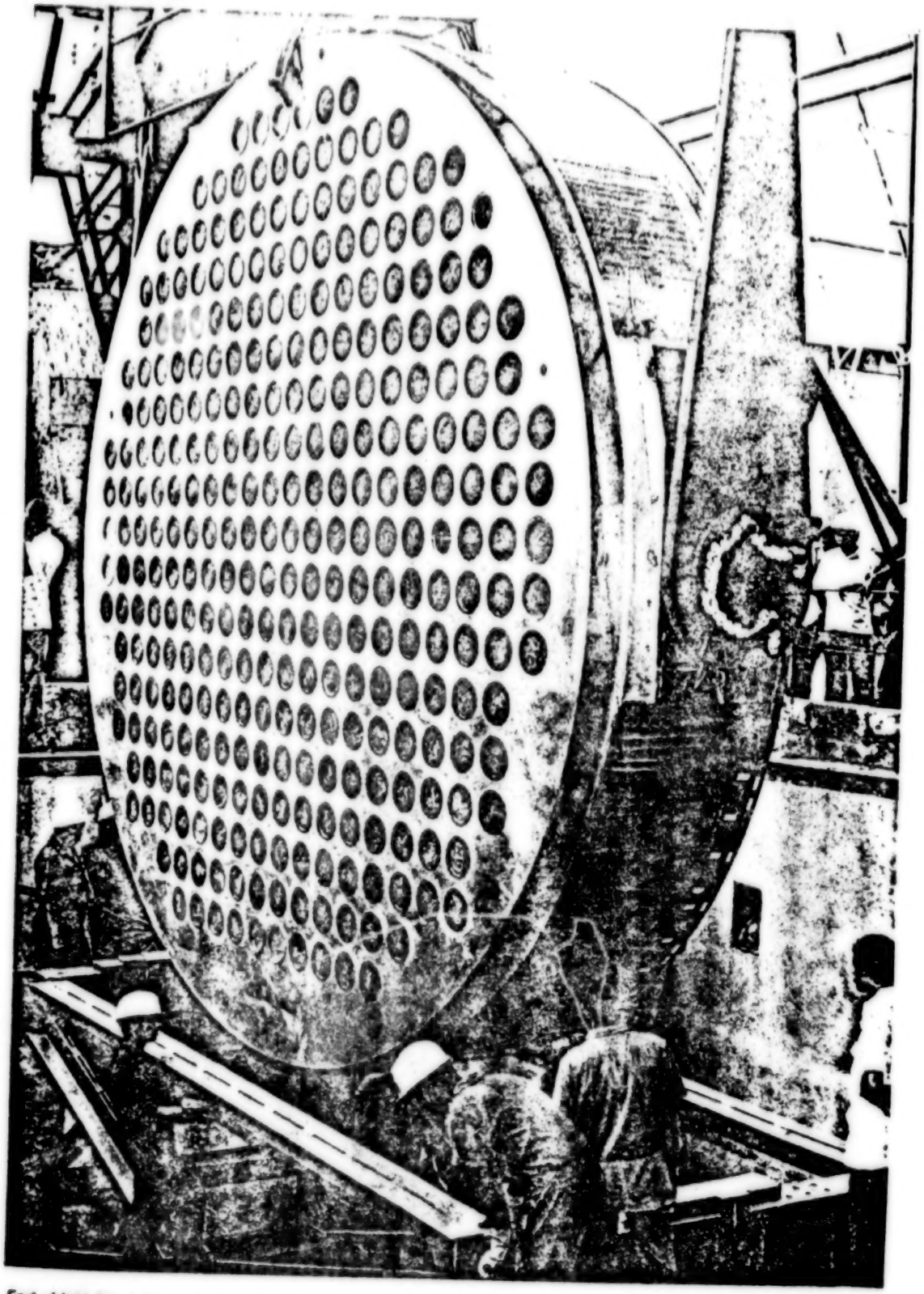

End shield No. 1 for Unit II of the Madras Atomic Power Station ,Kalpakkam, being taken into the reactor building for installation.

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